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A DETAILED STUDY OF CONTAMINANTS PRODUCED BY MAN IN A SPACE CABIN SIMULATOR AT 760 MM. HG

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FOREWORD

The research reported in this paper was conducted by personnel of the Environmental Systems Branch under task No. 7930-2 from 2 to 29 June 1965. This work was supported in part by NASA Manned Spacecraft Center (NASA contract R-89, which was monitored by Dr. Elliott Harris). The paper was submitted for publication on 7 December 1966.

Analytical support reported in this paper was performed by Arnold Engineering and Development Center (15), Lockheed Missiles and Space Company (14), Melpar, Inc. (4), Von Karman Center, Aerojet-General Corporation (13), and Traverlab/Research (3).

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This report has been reviewed and is approved.

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ABSTRACT

A 27-day experiment was conducted to determine man's contribution to trace contaminants in a sealed environment. An environmental test cell was maintained at a total pressure of 760 mm. Hg throughout the 27 days, with the first 13 days being unmanned and the last 14 days being manned. Four subjects were utilized during the 14-day manned portion of the test. During the 27 days, 97 compounds were identified and quantified; 21 of these compounds were noted only during the manned portion of the study. Direct contaminant analysis of the sealed environment was not adequate for this type of comprehensive survey. Cryogenic fractionation and concentration, however, provided samples with sufficient concentration of contaminants for analysis by means of gas chromatography, infrared spectroscopy, and mass spectroscopy. Carbon monoxide and carbon dioxide were compounds that were produced by man and identified in this experiment that would require removal during the 14-day period.

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A DETAILED STUDY OF CONTAMINANTS PRODUCED BY MAN IN A SPACE CABIN SIMULATOR AT 760 MM. HG

I. INTRODUCTION

Before extended manned space missions are accomplished, the individual and combined impact of trace contaminants in the sealed atmospheres of spacecraft must be carefully evaluated. Studies must be conducted to establish the source, concentration (or production rate), toxicology, and removal technics for the various atmospheric contaminants. This type of systematic study is essential to insure that trace contaminants are adequately controlled and do not limit the mission duration.

Earlier reports have provided information as to the atmospheric contaminants contributed by materials (10). A combination of man and materials in submarines, spacecraft (8), and ground-based simulators (1, 17) has been surveyed for similar purposes. Experiments specifically designed to delineate those contaminants produced by man have not been previously conducted. The atmospheric contaminant information gained to date has been as a by-product of experiments conducted with other specific objectives (1, 8, 17). The purpose of this paper is to present the results of a joint United States Air Force and National Aeronautics and Space Administration study designed to define within the limits of the analytical procedures (4, 13, 14, 15) those contaminants associated with human occupancy of a sealed environment in an oxygen-nitrogen atmosphere at 760 mm. Hg total pressure.

II. SUMMARY

The experiment was conducted at 760 mm. Hg with 20% oxygen and 80% nitrogen as the atmosphere. The study was divided into three parts: a preliminary stabilization period of 2 days; an unmanned background period of 11 days; and a manned period of 14 days. The unmanned portion provided information as to the contaminant materials associated with the test cell, previous occupancy by man, and support items required during the subsequent manned portion. The four volunteer subjects were sustained on a liquid diet and were permitted limited hygienic activity during their occupancy of the test cell.

Direct sampling and concentrating technics with subsequent analysis were utilized for contaminant detection. Dual flame-ionization gas chromatography and microwave spectrometry were used for the analysis of unconcentrated samples which were obtained directly from the chamber. Methane and carbon monoxide were analyzed by flame-ionization gas chromatography and infrared spectroscopy, respectively.

To concentrate the sample, multistage cryogenic trapping systems were operated daily during the 27-day study. Four sample sets were obtained daily and were analyzed by Arnold Engineering and Development Center, Lockheed Missiles and Space Company, Melpar, Inc., and Von Karman Center, Aerojet-General Corporation.

Rapid initial increases in methane and carbon monoxide were observed soon after man entered the test cell. The methane concentration increased from 20.9 mg./m.^{3} the day after man entered the chamber to a high of 84.6 mg./m.^{3} The concentration of carbon monoxide ranged from a low of 4.8 mg./m.^{3} to a high of 23.7 mg./m.^{3}

No significant data relating to organic compounds were obtained from the analyses of unconcentrated samples during either portion of the study. The cryogenically concentrated samples analyzed by gas chromatography, infrared spectroscopy, and mass spectroscopy yielded substantial information. Differential column flame-ionization chromatography combined with mass spectroscopy yielded the best results.

The four analyses groups identified a total of 97 trace compounds. The frequency and highest concentration of contaminants are presented in table IX. Of the 97 compounds reported (table IX), 21 compounds were reported only during the manned portion of the study (table X). The data were insufficient in consistency to predict production rates; however, several trends were demonstrated. A group of compounds which showed a consistent or decreasing concentration included toluene, methyl ethyl ketone, hexane, and xylene. These are indicative of solvents used in the chamber as well as those compounds added by the supply gases. Methyl alcohol, acetone, ethyl ether, and isoprene were examples of compounds which demonstrated an increase with inclusion of man into the sealed environment.

Carbon monoxide and carbon dioxide were identified as compounds which were produced by man at a rate that would require removal in a closed system operation.

The study clearly demonstrated that the state-of-the-art of analysis of trace contaminants has not progressed technically to the point of valid repeatability.

III. METHODS

Test facilities

A 27-day experiment was conducted within the USAF School of Aerospace Medicine four-man environmental test cell located at Brooks AFB, Tex. (fig. 1). The test cell used in this experiment is an advanced double-walled testing device for simulating manned spacecraft atmospheres. The complex is constructed of two separate pressure vessels (air lock and test cell) contained within a single vacuum vessel. An annular space exists between the inner and outer shells. An inner lock is formed by installing two doors on the sleeve connecting the air lock and test cell. The inner lock is small compared to the air lock and test cell to minimize contamination of the environment when the human subjects were transferred into the test cell.

The test cell is divided by panels and folding doors to form three distinct areas. The cockpit section contains two modified aircraft crew seats, instrument panels including displays for operation of internal equipment, and psychomotor test facilities. The crew seat cushions are constructed of slabs of polyester foam covered with a nylon fabric. The equipment area contains the environmental control system, galley, storage cabinets, toilet, and sink. The sleeping area contains two bunks (foam mattresses), storage cabinets, and a counter formed by a freezer and refrigerator.

Two pass locks are provided for transferring items such as carbon dioxide sorbent canisters, biologic specimens, and waste. The doors of the pass lock are constructed of carbon steel.

The test cell is designed to withstand a differential pressure of 15 p.s.i. in either direction. The principal material of construction is carbon steel; however, the large doors are of cast aluminum. Many of the work areas and cabinets are constructed of stainless steel to decrease the surface area that required a protective coating.

The interior surface of the test cell was initially sandblasted and treated with a zinc chromate primer. The final spray coat was the 400 series 3M brand "Velvet Coat" manufactured by Minnesota Mining and Manufacturing, Minneapolis, Minn.

The test cell total pressure was maintained above ambient conditions by the manual addition of makeup oxygen and nitrogen. This technic was used because the annulus pressure

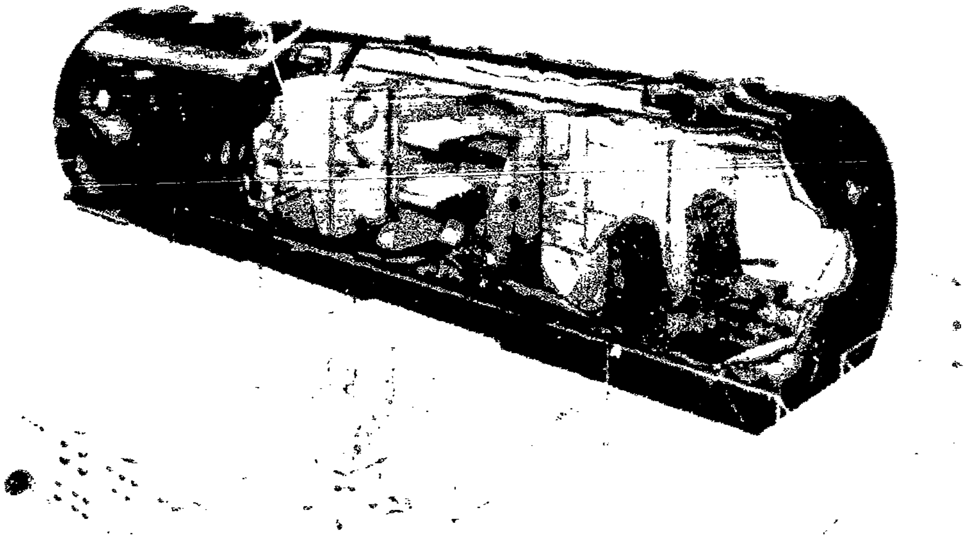


FIGURE 1

USAF School of Aerospace Medicine four-man environmental test cell.

remained essentially below the test cell pressure, thus providing an outboard leak. The amount of leakage was measured by a large Tissot spirometer which was connected to the annulus.

Thermal control within the test cell was maintained by the recirculation of the atmosphere through heat exchangers cooled by an ethylene glycol solution. The nominal capacity of the cabin cooler was 12,000 BTU per hour.

The test cell was ventilated by two centrifugal blowers each having a nominal capacity of 250 cubic feet per minute. The ventilation fans circulated the atmosphere from behind the perforated ceiling plates in the test cell into the intake duct of the environmental control system. A Fiberglas filter in the intake duct eliminated particles from the blowers and heat exchangers. After passing through the blowers, the atmosphere was circulated through the cabin cooler and then exhausted under the floor.

Part of the atmosphere was delivered to the atmospheric control subsystem where carbon dioxide and water vapor were removed. A dehumidifier coil was vertically oriented in the gas stream so that the condensate would flow down into the water separator. The dewpoint temperature of the atmosphere in the test cell was controlled to some degree by the flow of the ethylene glycol solution through the unit. Lithium hydroxide was contained in two canisters for sorption of carbon dioxide. A portion of the atmosphere was forced through one or both canisters to maintain the carbon dioxide partial pressure at the experimental conditions required.

A representative sample of the test cell atmosphere was analyzed for major constituents by a system which was operated at a constant pressure of 775 mm. Hg to avoid contamination by ambient air.

The analysis loop consisted of an air pump, heat exchanger, water trap, accumulator and relief valve, the analyzer bank with flow regulator, a back pressure regulator, and a signal division network. The air pump, located in the test cell, was a two-stage diaphragm pump with Teflon diaphragm and fluoroelastomer valves. The pump was capable of a compression ratio of at least 5:1 at an inlet pressure of 3 p.s.i.a. and a flow rate of 1 cubic foot per minute. The heat exchanger was used to cool the sample stream to a constant dewpoint of 5° C. with a water trap to collect the condensate. An accumulator and relief valve were provided to bypass the excess gas and return it to the test cell. The accumulator and the relief valve combination also reduced the pump pulsations and provided a constant pressure drop across the analyzers.

The analyzers in the test cell loop were a Beckman paramagnetic oxygen analyzer, a Mine Safety Appliance (MSA) "Lira" 300 carbon dioxide analyzer, a MSA "Lira" 300 carbon monoxide analyzer, and a Med-Science Electronic "Nitralyzer" for nitrogen determination.

The back pressure regulator was connected to the analyzer outlets and maintained a constant sensor pressure of 775 mm. Hg. A servo-driven divider network was used to correct the analyzer signals in order to display partial pressures as they existed in the test cell.

The test cell total pressure was maintained at 760 mm. Hg by the addition of oxygen and nitrogen. The atmosphere was supplied to the subjects at an oxygen partial pressure of 165 mm. Hg, the balance being composed of carbon dioxide, nitrogen, and water vapor. Accurate measurements of the amount of oxygen added were made on a weight basis, while nitrogen addition was monitored by pressure change in the supply system.

Support items

The chamber was provisioned before initiation of the experiment with the minimum required support items necessary for manned habitation. The lithium hydroxide canisters were the only support items which were interchanged during the course of the experiment. The stored food (Natick Laboratories, Natick, Mass.) was a synthetic (chocolate or vanilla flavored) liquid diet composed of water (68%), casein (5%), fat (8%), corn oil (0.2%), starch (2%), sugars (16.5%), and minerals. The caloric value of the food was 1.30 to 1.36 kcal./gm.

Subjects

The four volunteer airmen, 18 to 22 years of age, lived in the test cell during the manned portion of the study. The physical characteristics of the test subjects are presented in table I. The subjects underwent a complete medical evaluation in the Clinical Sciences Division, USAF School of Aerospace Medicine, immediately before and after their 14 days in the test cell. This evaluation included a complete physical examination with ophthalmologic, neurologic, and psychiatric consultations; hematologic and blood chemistry studies; urinalyses; electrocardiograms; electroencephalograms; chest roentgenograms; and stress testing. Hematologic studies included white blood cell and differential counts, hematocrit, hemoglobin, red blood cell count, reticulocyte count, and sedimentation rate. Blood chemistries included Bromsulphalein (BSP) retention, bilirubin, serum glutamic oxaloacetic

TABLE I

Physical characteristics of test subjects

Subject No.	Age (years)	Height (cm.)	Weight (kg.)
84	18	185	68.2
85	19	168	77.3
86	20	175	71.8
87	22	175	75.5

transaminase (SGOT), serum glutamic pyruvic transaminase (SGPT), total protein, serum protein electrophoresis, thymol turbidity, cephalin flocculation, blood urea nitrogen, creatinine, cholesterol, fasting blood sugar, and uric acid. The above blood studies were performed in a clinical laboratory by standard methods. Stress testing pre- and postexperimentally was performed by the Balke (2) treadmill test and the tilt-table orthostatic tolerance test.

In addition to the examinations outlined above, tests were performed to determine the presence or absence of methane in the flatus since it was desired that all four subjects be methane producers. Flatus was collected by inserting a Levine tube into the lower intestine and collecting the gas over water in the manner of Kirk (11). Subsequent analyses of the flatus were accomplished by gas chromatography.

During the habitation by human subjects, the major waste materials produced were isolated from the test cell atmosphere. The feces were collected in plastic bags and stored in a freezer before being removed from the test cell. After each voiding, urine was transferred overboard by way of a water trap unit which was subsequently well flushed with water. Loss of test cell atmosphere was thus avoided. Empty food cans were scrupulously rinsed before storage. Water was obtained from a line connected directly to the local water supply. The hygienic activity was limited to the dry brushing of the teeth and bathing with a damp cloth which was dried and stored. Soap and toothpaste were not made available, and the subjects did not shave while within the test cell.

Gas analysis

A 24-hour on-stream analysis of unconcentrated batch samples was provided to analyze the organic constituents of the test cell atmosphere. A dual flame gas chromatograph (Perkin-Elmer 800), equipped with 12-ft. Carbowax 4000–Amine 220 columns, was used for this purpose. A constant circulation from the chamber was established through the sample valves of the chromatograph, and a 5-ml. gas sample was introduced into the gas chromatograph on a periodic basis. To increase the apparent sensitivity of the chromatograph, several technics were used: (1) The 5-mv. chromatograph output signal was recorded on a 1-mv. recorder. (2) The supply gases for the chromatographic detector were of low organic content. (3) The gases were filtered through a gas purifier containing 5A molecular sieve. These technics were necessary in order to minimize the inherent background noise. The contaminant identifications were based on the retention time of the observed peaks. Calibration of the instrument was accomplished using three organic Matheson standards which provided a basis for quantitative and qualitative information.

Methane and carbon monoxide were determined during the study on a survey basis. Methane concentration was determined on a periodic basis with a MicroTek 1600 flame-ionization gas chromatograph. The instrument was equipped with a 7-ft., 5A molecular sieve (60/80 mesh) column. The information was recorded on a Honeywell recorder. Calibration was accomplished using standards prepared by this facility. Carbon monoxide was determined using a Beckman IR-7 with a 10-m. multipath IR cell with KBr windows. The path length used was 10 m. Double-beam operation with a 10-to-1 scale expansion was used for the determinations at a pressure of 760 mm. Hg. Measurements of peak depth referenced to a background IR-scan were used for optical density determinations. Calibration was accomplished using a 98 p.p.m. carbon monoxide standard prepared by Big Three Industrial Gas and Equipment Company, Houston, Tex.

Periodically, atmospheric samples of the test cell were obtained by filling a 300-cc. evacuated glass flask to chamber pressure. These flasks were forwarded to Tracerlab Research, Waltham, Mass., for microwave spectrometric analysis (3). The analysis was accomplished by sweeping the microwave spectrum from 18 to 40 GHz with an unlimited scan time.

Concentrated cryogenic samples were required to identify and quantitate the contaminants existing in the test cell (8). During

the study, two multistage cryogenic trapping systems (7) were operated 20 to 22 hours per day. Samples were obtained in 10- to 11-hour collection periods. This schedule resulted in the production of four sets of samples in a 24-hour period. Each set consisted of three stainless steel cylinders. Materials that were not collected consisted of oxygen, nitrogen, and compounds with sufficient vapor pressure at −175° C. to pass through the system. A closed loop of 500 s.c.c./min. [70° F. (21.1° C.) and 760 mm. Hg] was maintained from the test cell through the systems.

A sample of the test cell atmosphere first entered a flowmeter and then passed to the first trapping cylinder, which was maintained at a temperature of 0° C. with ice water (fig. 2). The gas, having passed through the ice-bath trapping cylinder, flowed through a heated inlet into the trapping cylinder maintained at −78° C. with pulverized Dry Ice. The Dry Ice required occasional tamping to insure contact with the wall of the trapping cylinder. The gas then passed to a trapping cylinder maintained at −175° C., where many of the materials not previously removed from the gas stream were condensed. The remaining gas was conducted to the vacuum inlet of a circulating pump and exhausted back to the test cell atmosphere.

The trapping cylinders were stainless steel with an internal volume of about 150 cc. (figs. 3 and 4). The cylinders were fitted with Swagelok connections, modified pipe fittings, and needle valves. Teflon and stainless steel were used throughout the system to minimize catalytic conversions and contamination of samples. Gas stream temperatures were measured with copper-constantan thermocouples.

In the −78° C. trapping cylinder there tends to be a rapid ice formation in the inlet

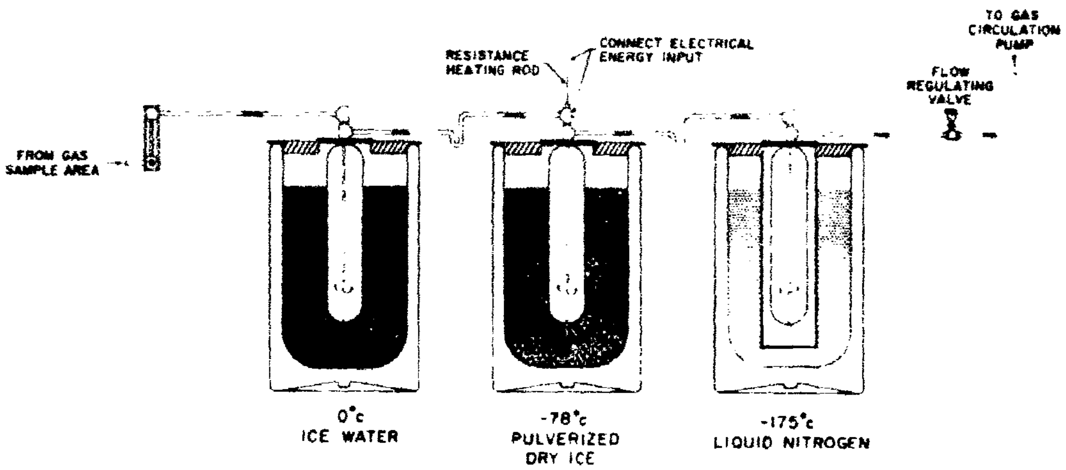
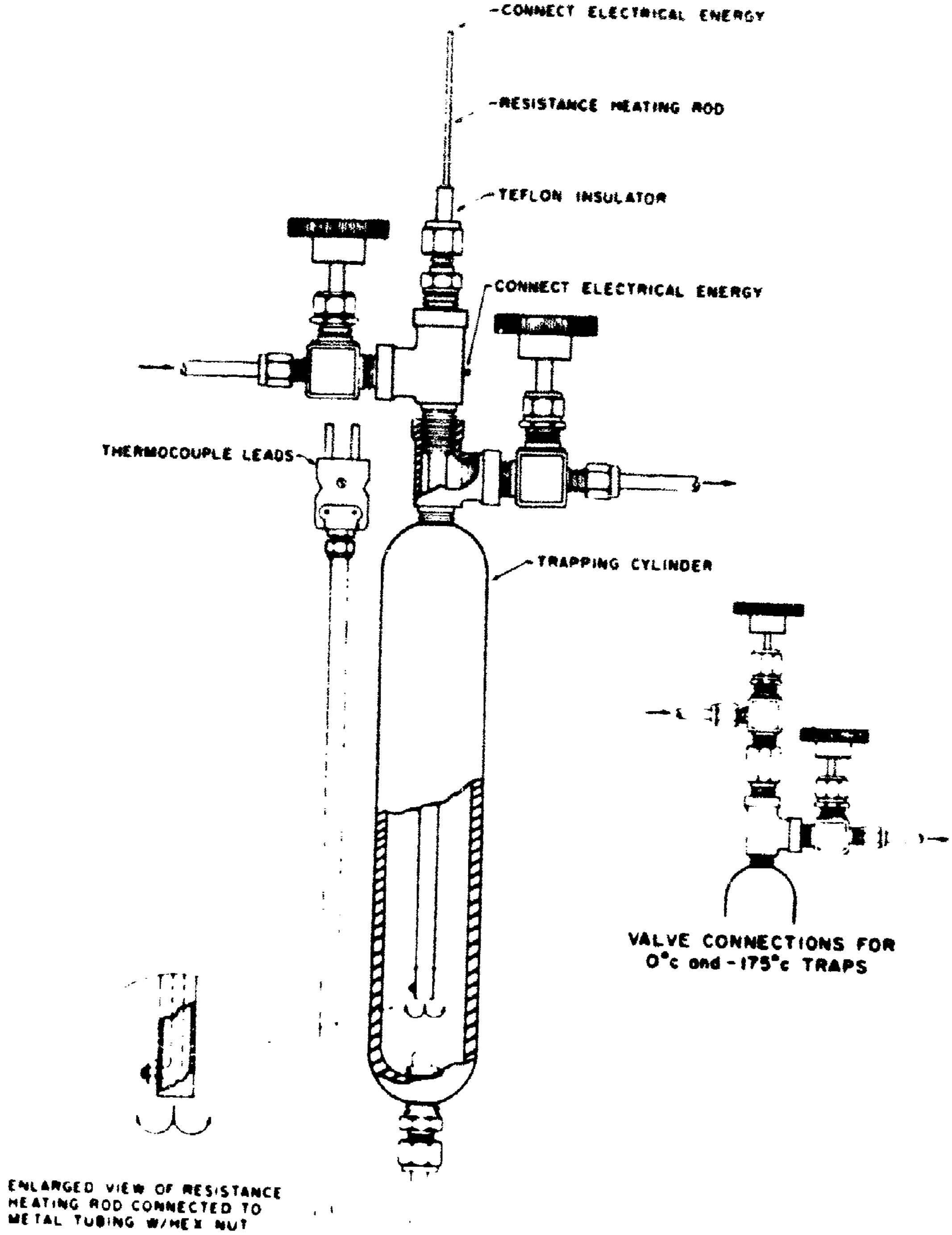


FIGURE 2

Gas flow path for multistage cryogenic trapping system.

FIGURE 3

Diagrammatic cross section of multistage cryogenic trapping cylinders.


CONNECT ELECTRICAL ENERGY
RESISTANCE HEATING ROD
TEFLON INSULATOR
CONNECT ELECTRICAL ENERGY
THERMOCOUPLE LEADS
TRAPPING CYLINDER
VALVE CONNECTIONS FOR
0°c and -175°c TRAPS
ENLARGED VIEW OF RESISTANCE
HEATING ROD CONNECTED TO
METAL TUBING W/HEX NUT

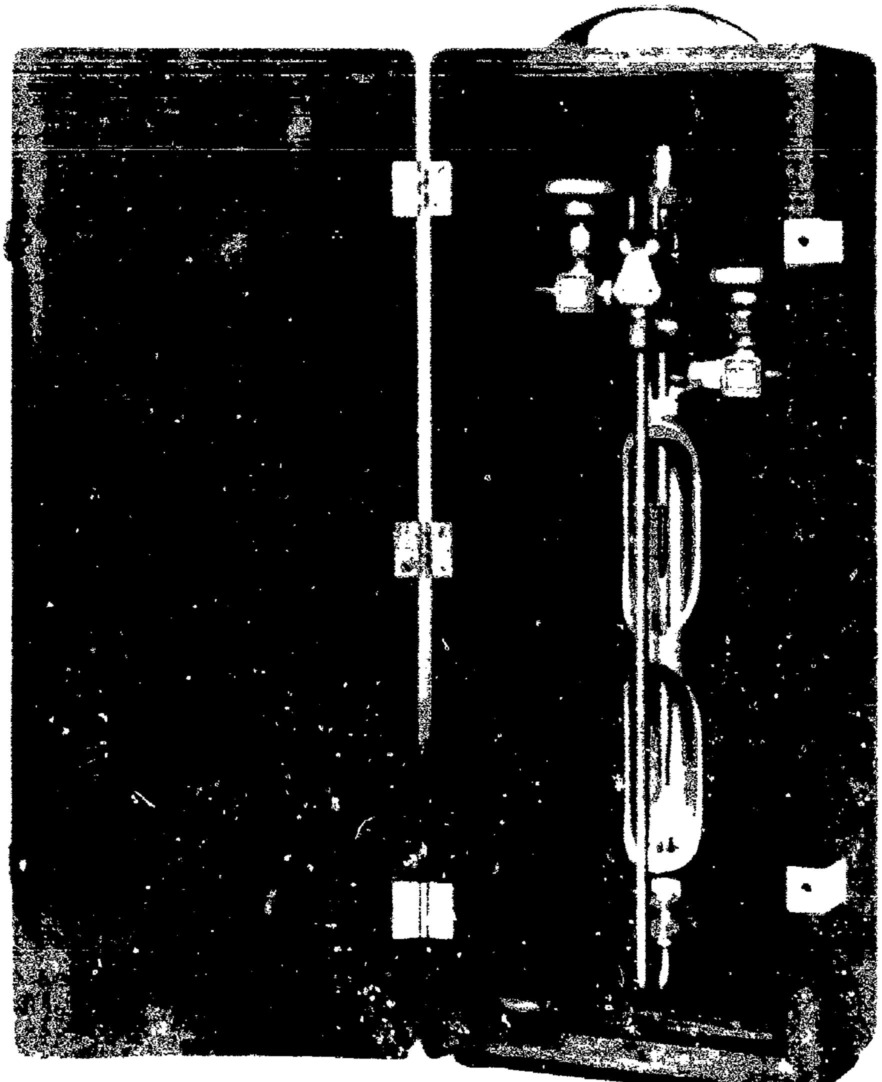


FIGURE 4

Cut-away of trapping cylinder.

tube. This formation, due to the temperature gradient along (or down) the entrance tube, was prevented by the application of heat. The heater consisted of a 1/16-inch stainless steel rod inserted through a Teflon-insulated Swagelok fitting at the top of the cylinder. It was positioned in the center of the entrance tube and projected to the bottom where it was welded to the wall of the entrance tube. This connection served as an electrical contact between the cylinder and the rod. Electrical energy from a variable transformer was applied across the primary of a filament transformer, the secondary of which was connected

to the rod and cylinder wall. Sufficient energy was applied to the heater to prevent the formation of ice in the tube without affecting the operational temperature of the trap.

The final trapping cylinder was controlled at a temperature of 175° C. in order to prevent the formation and entrapment of liquid oxygen (183° C. at standard pressure). The presence of liquid oxygen in the trap would have presented an explosive hazard for personnel handling the cylinders, and it would have made available a supply of oxygen for degradation of the original contaminants and the formation of new compounds. This cylinder was positioned with two glass-phenolic rings in a well which was surrounded by liquid nitrogen. The well was positioned by a fitted lid for the Dewar flask. The lid also contained a vent, a well for the liquid nitrogen level sensor, and the liquid nitrogen filling device (fig. 5).

Temperature control of the trap cylinder was maintained by a flow of dry warm nitrogen from the bottom of the well. The flow of gaseous nitrogen was regulated with a micrometer needle valve. One of the glass-phenolic rings positioning the cylinder covered the top of the well and maintained a positive pressure of gaseous nitrogen, thus preventing the back diffusion of atmospheric air and the subsequent formation of liquid oxygen.

The cryogenic trapping system would concentrate a compound if the vapor pressure at the trap temperature was less than its partial pressure in the sample stream. Partial separation of compounds occurred owing to the different operational temperatures of the three traps.

Table II depicts the distribution of several compounds as a function of temperature at which they would be expected to be concentrated in significant quantities. Substances are identified in each column according to the state in which they would exist at that temperature, either as a liquid (L) or as a solid (S). Any material existing as a solid at a given temperature should not be found concentrated in a succeeding trapping cylinder; however, liquid that has a significant vapor pressure at the temperature of liquefaction may be found in a succeeding trap. Therefore, complete removal of a compound from the sample stream may not occur if the compound appears as a liquid in the final trap. After liquefaction or solidification or both, there will be no significant transfer of particulate material from the traps in the form of fog or snow.

Experimental methods

To distinguish those contaminants produced by man from those associated with the test cell, support equipment and previous occupancy, the test cell was operated unmanned for a period of 13 days.

A 2-day preliminary operational stabilization period and cryogenic trapping began at 0715 hours, 2 June 1965. The test cell was pressurized at 1430 hours, 2 June 1965, and the system was operated minus lithium hydroxide canisters for sorption of carbon dioxide. The preliminary operational stabilization period was completed at 1607 hours, 4 June 1965.

At 1725 hours the test cell was evacuated to 156 mm. Hg total pressure with a liquid oxygen flush. Beginning at 1915 hours nitrogen from a liquid nitrogen source was added to the test cell to establish a pressure of 760 mm. Hg. The contaminant background of the test cell was obtained for an 11-day period beginning at 2223 hours. The background period was completed when the cryogenic samples were disconnected from the test cell at 0408 hours, 15 June 1965.

The subsequent 14-day manned portion of the experiment was begun at 0600 hours, 15 June 1965, with operation of the cryogenic trapping systems. The subjects were placed into the test cell through the inner lock, which was flushed with oxygen before pressurization to 760 mm. Hg. This permitted entry without depressurization or contamination of the test cell. Two subjects were placed into the test cell at 0605 hours. The other two subjects entered the test cell at 0615 and 1130 hours. The manned portion of the experiment was completed at 0400 hours, 29 June 1965.

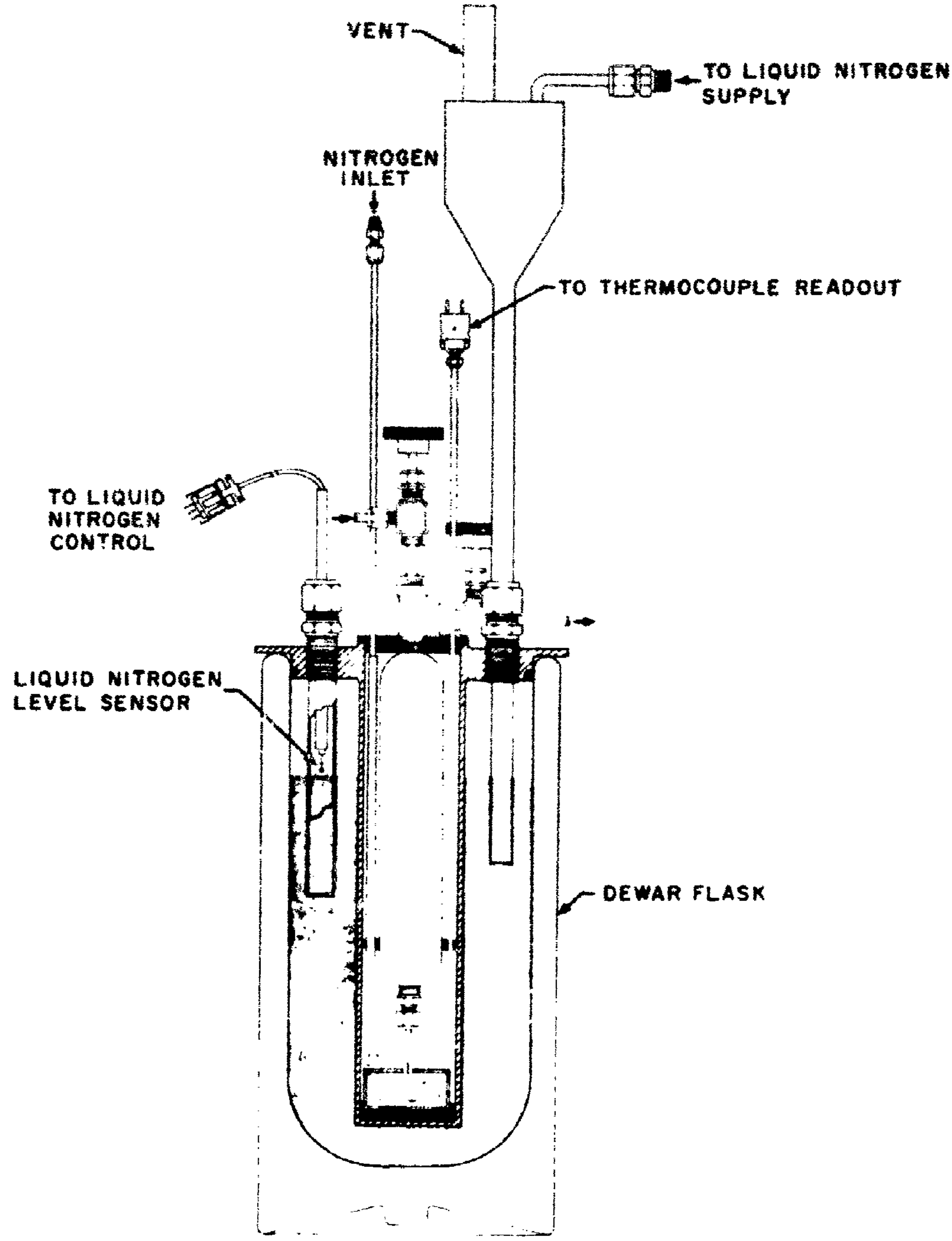


FIGURE 5

Diagrammatic cross section of liquid nitrogen trap.

TABLE II

Distribution of compounds by trapping cylinder temperature

Multistage cryogenic trapping cylinder			Untrapped
0° C.	−78° C.	−175° C.	
Water(L)	Water(S)	Acetone(S)	Methane
Ethylene glycol(L)	Freon 12(L)	Hydrogen sulfide(S)	Nitrogen
	Benzene(S)	Nitrous oxide(S)	Oxygen
	Toluene(S)	Sulfur dioxide(S)	Hydrogen
	Ethylene glycol(S)	Trimethyl amine(S)	Carbon monoxide
	Diethyl ether(L)	Monoethyl amine(S)	
	Trimethyl amine(L)	Freon 12(S)	
	Monoethyl amine(L)	Methyl mercaptan (S)	
		Carbon dioxide(S)	
		Ammonia(S)	
		Methanol(S)	
		Carbon tetrachloride(S)	

(L) = Liquid.
(S) = Solid.

Data reduction

An analysis of the material contained in the cylinder sets obtained from the cryogenic trapping systems was provided by Arnold Engineering and Development Center (ARO), Inc. (A); Lockheed Missiles and Space Corporation (L); Melpar, Inc. (M); and Von Karman Center, Aerojet-General Corporation (V) (see tables III to VI). Each group received a daily air shipment of one set of cylinders packed in Dry Ice.

The procedures used and results of analyses have been reported elsewhere (3, 4, 13, 14, 15).

The average test cell concentration in milligrams per cubic meter of a compound was evaluated using the following equation:

$$\frac{\text{Milligrams}}{\text{Liters}} \times 10^3 = \text{mg. m.}^3$$

where milligrams was that quantity reported by the contractors and where liters was obtained by multiplying the average flow rate in liters per minute by the time of the trapping period in minutes.

To determine the test cell concentrations in milligrams per cubic meter, considering a zero leak condition, the average test cell concentration calculated above was corrected for the effective leak. The effective gas leak consisted of the total gas leak plus a value for the gas processed through the cryogenic systems from which the contaminants were removed for analysis. The total gas leak consisted of the following: (1) the loss of gas into the annular space of the test cell; (2) the volume removed for batch analysis (IR-7 for carbon monoxide, MicroTek 1600 for methane and Tracerlab samples); (3) the volume lost when calibrating the Perkin-Elmer 800; and (4) the volume of the cryogenic systems when the cylinders were removed from the system.

Measured volumes of 4.2 liters for the Beckman IR-7 10-m. cell, 1.0 liter for the MicroTek 1600, 1.77 liters for the Perkin-Elmer 800, 0.31 liter for the Tracerlab samples, and 2.036

TABLE III

Cryogenic trapping system information for Arnold Engineering and Development Center

Sample identification	2 to 28 June 1965	Sampling time	Av. flow rate (s.c.c./min.*)	Time of operation (min.)	Av. test cell pressure (mm. Hg)	Av. test cell temp. (°C.)
			Unmanned			
65-2-6-2-2AA	2	1830-0438	500	600.2	760.6	22.3
65-2-6-3-1BA	3	0558-1538	500	576.0	760.3	22.1
65-2-6-4-2BA	4	2223-0503	474	396.2	760.4	22.5
65-2-6-5-2AA	5	1900-0503	500	600.9	753.8	22.2
65-2-6-6-1BA	6	0630-1630	492	600.0	757.1	22.1
65-2-6-7-1BA	7	0602-16[illegible]	500	600.4	756.3	22.4
65-2-6-8-1BA	8	0600-1600	500	600.0	757.7	22.6
65-2-6-9-2AA	9	1700-0300	500	600.1	756.0	22.7
65-2-6-10-1BA	10	0600-1600	500	600.3	756.4	22.4
65-2-6-11-2BA	11	1805-0507	500	660.1	757.1	22.8
65-2-6-12-2AA	12	1833-0430	500	600.0	754.2	22.7
65-2-6-13-2AA	13	1800-0400	500	600.1	755.6	22.9
65-2-6-14-1BA	14	0603-1700	500	660.1	754.6	23.0
			Manned			
65-2-6-15-2BA	15	1830-0429	500	600.0	755.4	23.9
65-2-6-16-1BA	16	0604-1700	500	660.0	753.7	23.7
65-2-6-17-1BA	17	0602-1617	499	613.6	755.5	23.6
65-2-6-18-2AA	18	1800-0400	500	600.9	758.0	23.7
65-2-6-19-2BA	19	1815-0417	493	600.0	758.3	22.5
65-2-6-20-2AA	20	1730-0333	500	601.[illegible]	757.7	24.0
65-2-6-21-2AA	21	1800-0402	499	600.1	759.4	23.8
65-2-6-22-2BA	22	1803-0410	491	600.0	757.7	23.7
65-2-6-23-1BA	23	0605-1707	500	660.0	756.2	23.9
65-2-6-24-1BA	24	0605-1700	500	660.0	756.8	23.9
65-2-6-25-2AA	25	1800-0400	474	600.2	755.8	23.9
65-2-6-26-2BA	26	1830-0400	493	600.1	755.7	23.7
65-2-6-27-2BA	27	1802-0405	490	602.2	757.4	23.7
65-2-6-28-1BA	28	0630-1730	495	660.0	759.4	23.6

*70° F. and 760 mm. Hg.

liters for the volume of the cryogenic systems were converted from volumes at test cell conditions to volumes at 21.1° C. and 760 mm. Hg by gas law conversion. The gas which leaked from the test cell into the annular space was measured by a Tissot spirometer. The total and effective leak as related to each batch sample and cryogenically obtained sample set was used to determine the concentration in milligrams per cubic meter of each compound, considering zero gas leak from the test cell. Before correction to a zero leak condition was undertaken, consideration was given to those compounds added to the test cell by the supply gases (tables VII and VIII). In each instance the milligrams contained within the test cell were reduced by subtracting that quantity of material added during a given trapping period.

TABLE IV

Cryogenic trapping system information for Lockheed Missiles and Space Company

Sample identification	2 to 28 June 1965	Sampling time	Av. flow rate (s.c.c./min.*)	Time of operation (min.)	Av. test cell pressure (mm. Hg)	Av. test cell temp. (°C.)
			Unmanned			
65-2-6-2-2BL	2	1830-0430	500	600.4	760.6	22.3
65-2-6-3-2AL	3	1900-0500	500	600.0	747.5	22.2
65-2-6-4-2AL	4	2223-0502	472	401.8	760.4	22.5
65-2-6-5-2BL	5	1915-0615	500	600.3	753.8	22.2
65-2-6-6-2AL	6	1730-0335	500	600.1	754.4	22.5
65-2-6-7-2AL	7	1800-0401	500	600.1	756.6	22.7
65-2-6-8-2AL	8	1800-0404	500	600.2	757.8	22.8
65-2-6-9-1BL	9	0600-1600	496	600.0	756.1	22.4
65-2-6-10-2AL	10	1703-0455	500	503.1	757.0	23.6
65-2-6-11-2AL	11	1800-0505	500	660.1	757.1	22.8
65-2-6-12-2BL	12	1815-0415	500	601.1	754.2	22.7
65-2-6-13-1AM	13	0600-1700	500	660.0	755.4	22.4
65-2-6-14-2BL	14	1800-0406	500	600.1	753.4	23.8
			Manned			
65-2-6-15-2AL	15	1830-0425	500	600.0	755.4	23.9
65-2-6-16-2AL	16	1800-0358	500	600.0	758.5	23.5
65-2-6-17-2BL	17	1803-0403	500	600.0	758.[illegible]	23.6
65-2-6-18-1BL	18	0603-1700	500	660.0	758.1	23.7
65-2-6-19-2AL	19	1806-0114	500	302.3	758.3	23.5
65-2-6-20-1BL	20	0647-1625	322	491.2	757.4	23.6
65-2-6-21-1BL	21	0608-1710	500	660.0	756.1	23.7
65-2-6-22-1BL	22	0602-1700	516	660.0	756.7	23.6
65-2-6-23-2BL	23	1800-0357	500	600.1	758.9	23.7
65-2-6-24-2AL	24	1800-0402	500	600.2	757.0	23.6
65-2-6-25-1BL	25	0605-1700	500	660.1	755.2	23.8
65-2-6-26-1BL	26	0630-1732	500	660.0	755.0	23.7
65-2-6-27-1BL	27	0605-1600	500	660.0	755.3	23.6
65-2-6-28-2AL	28	1800-0400	500	600.0	756.3	23.8

*70° F. and 760 mm. Hg.

IV. RESULTS

Ninety-seven trace compounds were collectively reported by the four analytical groups performing the analysis of the cryogenically obtained samples. The analytical procedures and the milligrams collected per cylinder set have been reported as raw data (4, 13, 14, 15). The frequency of occurrence and the highest average test cell concentration of contaminants are shown in table IX.

The compounds identified only during the manned portion of the experiment are listed in table X.

During the study 29 compounds were reported by Arnold Engineering and Development Center (table XI). Two compounds, trichloroethylene and ethylene, were reported by Arnold only during the manned portion; however, they were reported by others during

TABLE V

Cryogenic trapping system information for Melpar, Inc.

Sample identification	2 to 28 June 1965	Sampling time	Av. flow rate (s.c.c./min.*)	Time of operation (min.)	Av. test cell pressure (mm. Hg)	Av. test cell temp. (°C.)
			Unmanned			
65-2-6-2-1AM	2	0715-1715	500	600.0	749.5	24.8
65-2-6-3-1AM	3	0558-1600	500	600.0	760.3	22.1
65-2-6-4-1AM	4	0605-1607	500	600.0	749.4	22.2
65-2-6-5-1AM	5	0608-1815	500	727.0	758.4	22.3
65-2-6-6-1AM	6	0630-1630	500	600.3	757.1	22.1
65-2-6-7-1AM	7	0600-1600	500	600.2	756.3	22.4
65-2-6-8-1AM	8	0600-1600	500	600.0	757.7	22.6
65-2-6-9-1AM	9	0600-1600	500	600.0	756.1	22.4
65-2-6-10-1AM	10	0600-1600	500	600.0	756.1	22.4
65-2-6-11-1AM	11	0610-1710	500	660.0	756.5	23.2
65-2-6-12-1AM	12	0637-1737	500	660.0	757.5	22.4
65-2-6-13-1BL	13	0602-1700	499	600.0	755.4	22.4
65-2-6-14-1AM	14	0600-1700	500	660.0	754.8	23.0
			Manned			
65-2-6-15-1AM	15	0600-1705	500	660.0	751.5	23.7
65-2-6-16-1AM	16	0600-1700	500	660.0	753.5	23.7
65-2-6-17-1AM	17	0600-1618	500	616.0	755.5	23.6
65-2-6-18-1AM	18	0600-1700	500	660.0	758.1	23.7
65-2-6-19-1AM	19	0600-1700	500	660.0	760.8	23.6
65-2-6-20-1AM	20	0644-1625	252	570.0	757.4	23.6
65-2-6-21-1AM	21	0605-1705	500	660.0	756.1	23.7
65-2-6-22-1AM	22	0600-1700	500	660.0	756.7	23.6
65-2-6-23-1AM	23	0600-1700	500	660.0	756.2	23.9
65-2-6-24-1AM	24	0600-1700	500	660.0	756.8	23.9
65-2-6-25-1AM	25	0600-1700	500	660.0	755.2	23.8
65-2-6-26-1AM	26	0630-1730	500	660.0	755.0	23.7
65-2-6-27-1AM	27	0600-1700	500	660.0	755.3	23.6
65-2-6-28-1AM	28	0625-1650	430	625.0	759.4	23.6

*70° F. and 760 mm. Hg.

the unmanned portion. The other 27 compounds were reported either during the unmanned portion or during both portions of the experiment.

Lockheed Missiles and Space Company reported 40 compounds (table XII). Of these, 2-butene (cis) and allene were reported only during the manned portion. Three additional compounds (methyl acetate, isopropyl ether, and 1-pentene) reported by Lockheed as being present only during the manned portion were reported by others during the unmanned portion. The other 35 compounds were reported either during the unmanned portion or during both portions of the experiment.

TABLE VI

Cryogenic trapping system information for Von Karman Center

Sample identification	2 to 28 June 1965	Sampling time	Av. flow rate (s.c.c./min.*)	Time of operation (min.)	Av. test cell pressure (mm. Hg)	Av. test cell temp. (°C.)
			Unmanned			
65-2-6-2-1BV	2	0730-1730	501	600.0	749.5	24.8
65-2-6-3-2BV	3	1900-0502	500	600.1	747.5	22.2
65-2-6-4-1BV	4	0605-1550	498	580.0	749.4	22.2
65-2-6-5-1BV	5	0609-1830	500	738.0	758.4	22.3
65-2-6-6-2BV	6	1730-0337	500	600.0	754.4	22.5
65-2-6-7-2BV	7	1802-0403	500	600.0	756.6	22.7
65-2-6-8-2BV	8	1803-0403	500	600.4	757.8	22.8
65-2-6-9-2BV	9	1703-0303	500	600.0	756.0	22.7
65-2-6-10-2BV	10	1704-0447	500	530.8	757.0	23.2
65-2-6-11-1BV	11	0605-1700	500	660.0	756.5	23.2
65-2-6-12-1BV	12	0640-1712	500	631.7	757.5	22.4
65-2-6-13-2BV	13	1800-0400	500	601.0	753.6	22.9
65-2-6-14-2AV	14	1803-0408	500	600.1	753.4	23.8
			Manned			
65-2-6-15-1BV	15	0605-1725	500	660.0	754.5	23.7
65-2-6-16-2BV	16	1802-0400	500	600.1	758.5	23.5
65-2-6-17-2AV	17	1800-0400	497	600.0	758.4	23.6
65-2-6-18-2BV	18	1803-0403	499	600.5	758.0	23.7
65-2-6-19-1BV	19	0603-1700	500	660.0	760.8	23.6
65-2-6-20-2BV	20	1730-0332	500	600.7	757.7	24.0
65-2-6-21-2BV	21	1802-0404	496	600.5	759.4	23.8
65-2-6-22-2AV	22	1800-0407	269	600.0	757.7	23.7
65-2-6-23-2AV	23	1800-0356	500	600.0	758.9	23.7
65-2-6-24-2BV	24	1802-0405	496	600.0	757.0	23.6
65-2-6-25-2BV	25	1801-0400	460	600.0	755.8	23.9
65-2-6-26-2AV	26	1825-0429	486	600.0	755.7	23.7
65-2-6-27-2AV	27	1800-0407	487	601.1	757.4	23.7
65-2-6-28-2BV	28	1800-0400	499	600.1	756.3	23.8

*70° F. and 760 mm. Hg.

Of the 29 compounds reported by Melpar, Inc., 5 (methane, ethane, isopropyl alcohol, perchloroethylene, and heptane) were reported only during the manned portion (table XIII). Methane was the only compound not reported by others as being present during the unmanned portion. The other 24 compounds were reported during both portions of the experiment.

The Von Karman Center reported 70 compounds (table XIV); 20 of these were reported only during the manned portion (propionic acid, valeric acid, butyraldehyde, mesitylene, methyl n-butyrate, butyl acetate, furan, dimethyl furan, 1,4-dimethoxybenzene, benzyl ether, pentafluoroethane, Freon 113, skatole, decalin, decalin isomers, methane, ethane, propyl mercaptan, ethylene, and methyl

amine). Of these 20 compounds, ethane and ethylene were reported by others during the unmanned portion The other 50 compounds were reported either during the unmanned portion or during both portions of the experiment.

The carbon monoxide concentration in milligrams per cubic meter, as determined by the Beckman IR-7 and Lira analyzer, is presented in table XV. During the unmanned portion of the experiment, the mean carbon monoxide concentration was 1.7 mg./m.³ A substantial increase in average test cell concentration was observed during the manned portion of the experiment. During the first day, the average concentration was 4.8 mg./m.³ A high of 23.7 mg./m.³ for the daily average test cell concentration occurred on the last day of the manned portion.

TABLE VII

Contaminants in supply oxygen

Compound by chemical class	Concentration (mg./m.³)
Alcohols	
Methyl alcohol	0.000756
Ethyl alcohol	0.084034
Aromatic hydrocarbons	
Toluene	0.000378
Ethers	
Ethyl ether	0.000059
Isopropyl ether	0.000966
Halogen derivatives of ethane	
Methyl chloroform	0.000202
Halogen derivatives of ethylene	
Vinyl chloride	0.002521
Halogen derivatives of methane	
Chloroform	0.039916
Freon 22	0.000504
Ketones	
Acetone	0.005462
Methyl ethyl ketone	0.006303
Paraffins	
Ethane	0.000345
Hexane	0.000202

TABLE VIII

Contaminants in supply nitrogen

Compound by chemical class	Concentration (mg./m.³)
Organic acids	
Acetic acid	0.001249
Propionic acid	0.000416
Aromatic hydrocarbons	
Benzene	0.006243
o-Xylene	0.011237
Pseudocumene	0.003329
Mesitylene	0.041617
Naphthalene	0.000416
Esters	
Methyl acetate	0.002539
Butyl acetate	0.000250
Methyl n-butyrate	0.002081
Ethers	
Tetrahydrofuran	0.035791
Halogen derivatives of ethane	
Freon 114	0.001249
Halogen derivatives of ethylene	
Methyl chloroform	0.004162
Trichloroethylene	0.004162
Halogen derivatives of methane	
Methylene chloride	0.000416
Indoles	
Skatole	0.000416
Ketones	
Acetone	0.004994
Methyl ethyl ketone	0.000208
Naphthenes	
Cyclohexane	0.000042
Methyl cyclohexane	0.000208
Dimethyl cyclohexane	0.000832
Decalin	0.000832
Indene	0.000042
Paraffins	
Hexane	0.000042
Isopentane	0.000083
2,3-Dimethyl butane	0.000042
Olefins	
Ethylene	0.000250
Diolefins	
Isoprene	0.000999

TABLE IX

Frequency of occurrence and highest concentration of test cell contaminants

Compound by chemical class		Arnold		Lockheed		Melpar		Von Karman	
		Freq.*	Conc. (mg./m.^{3})	Freq.	Conc. (mg./m.^{3})	Freq.	Conc. (mg./m.^{3})	Freq.	Conc. (mg./m.^{3})
Inorganic acids									
Hydrogen fluoride	(Unmanned)	11/11	0.51000						
	(Manned)	14/14	1.30000						
Carbon dioxide	(Unmanned)	11/11	930.00000	10/11	980.00000	10/10	410.00000	10/10	2,400.00000
	(Manned)	14/14	6,500.00000	13/14	6,100.00000	14/14	14,000.00000	14/14	5,500.00000
Organic acids									
Acetic acid	(Unmanned)							1/10	0.00130
	(Manned)							7/14	0.00330
Propionic acid	(Unmanned)							0/10	
	(Manned)							3/14	0.00270
Valeric acid	(Unmanned)							0/10	
	(Manned)							5/14	0.00570
Alcohols									
Methyl	(Unmanned)	11/11	0.34000			6/10	0.00630	5/10	0.04700
	(Manned)	14/14	0.27000			5/14	0.03600	10/14	0.65000
Ethyl	(Unmanned)	9/11	0.09300	1/11	0.00130	10/10	0.16000	2/10	0.14000
	(Manned)	14/14	2.90000	0/14		13/14	0.04500	11/14	0.06000
Allyl	(Unmanned)			7/11	0.11000	1/10	0.01600	1/10	0.00380
	(Manned)			4/14	0.03600	6/14	0.02900	0/14	
n-Propyl	(Unmanned)			1/11	0.00070			0/10	
	(Manned)			1/14	0.02400			0/14	
Isopropyl	(Unmanned)	9/11	0.49000			0/10		7/10	0.03300
	(Manned)	14/14	7.80000			1/14	0.00730	8/14	0.03000
Butyl	(Unmanned)					9/10	0.01800	0/10	
	(Manned)					11/14	0.03000	0/14	
Isobutyl	(Unmanned)					3/10	0.00093	1/10	0.00250
	(Manned)					3/14	0.00220	2/14	0.02000

TABLE IX (contd.)

Compound by chemical class		Arnold		Lockheed		Melpar		Von Karman	
		Freq.*	Conc. (mg./m.^{3})	Freq.	Conc. (mg./m.^{3})	Freq.	Conc. (mg./m.^{3})	Freq.	Conc. (mg./m.^{3})
Aldehydes									
Acetaldehyde	(Unmanned)	11/11	0.26000	0/11		0/10		9/10	0.03030
	(Manned)	14/14	0.34000	0/14		0/14		6/14	0.05200
Butyraldehyde	(Unmanned)							0/10	
	(Manned)							4/14	0.00180
Aromatic hydrocarbons									
Benzene	(Unmanned)	7/11	0.16000	11/11	0.07000			9/10	0.08000
	(Manned)	7/14	2.70000	13/14	0.06400			12/14	0.05400
Toluene	(Unmanned)	11/11	0.06900	10/11	0.07800	10/10	0.17000	9/10	0.38000
	(Manned)	14/14	0.68000	12/14	0.05600	14/14	0.48000	14/14	0.05300
Styrene	(Unmanned)	0/11		0/11		0/10		2/10	0.04300
	(Manned)	0/14		0/14		0/14		0/14	
o-Xylene	(Unmanned)	7/11	3.20000	10/11	0.02800	10/10	0.02400	8/10	0.57000
	(Manned)	9/14	0.04600	12/14	0.00780	12/14	0.02800	10/14	0.01400
Ethyl benzene	(Unmanned)	0/11		11/11	0.02000	0/10		1/10	0.03200
	(Manned)	0/14		8/14	0.00450	0/14		8/14	0.00360
Pseudocumene	(Unmanned)			0/11				2/10	0.00230
	(Manned)			0/14				5/14	0.00230
Mesitylene	(Unmanned)							0/10	
	(Manned)							5/14	0.00650
Naphthalene	(Unmanned)							10/10	0.01100
	(Manned)							10/14	0.00530
Tetramethylbenzene	(Unmanned)							1/10	0.00030
	(Manned)							1/14	0.00003
Methyl naphthalene	(Unmanned)							3/10	0.01000
	(Manned)							5/14	0.01400
Dimethyl naphthalene	(Unmanned)							1/10	0.00027
	(Manned)							1/14	0.00041

TABLE IX (contd.)

Compound by chemical class		Arnold		Lockheed		Melpar		Von Karman	
		Freq.*	Conc. (mg./m.^{3})	Freq.	Conc. (mg./m.^{3})	Freq.	Conc. (mg./m.^{3})	Freq.	Conc. (mg./m.^{3})
Amines									
Methyl amine	(Unmanned)							0/10	
	(Manned)							1/14	0.00003
Esters									
Methyl acetate	(Unmanned)	0/11		0/11				1/10	0.07300
	(Manned)	0/14		1/14	0.00230			6/14	0.02400
Ethyl formate	(Unmanned)							5/10	0.00350
	(Manned)							4/14	0.00440
Ethyl acetate	(Unmanned)					1/10	0.00037	5/10	0.05400
	(Manned)					2/14	0.00250	6/14	0.16000
n-Propyl acetate	(Unmanned)					2/10	0.00820		
	(Manned)					2/14	0.00230		
Methyl n-butyrate	(Unmanned)							0/10	
	(Manned)							4/14	0.00210
Butyl acetate	(Unmanned)							0/10	
	(Manned)							5/14	0.01700
Ethers									
Furan	(Unmanned)							0/10	
	(Manned)							8/14	0.02100
Tetrahydrofuran	(Unmanned)	2/11	2.30000					8/10	0.57000
	(Manned)	7/14	0.44000					13/14	0.60000
Ethyl ether	(Unmanned)			4/11	0.01000	2/10	0.04000	9/10	0.14000
	(Manned)			11/14	1.00000	8/14	1.40000	9/14	0.34000
Methyl furan	(Unmanned)							2/10	0.02600
	(Manned)							2/14	0.00018
Dioxane	(Unmanned)			3/11	0.01200				
	(Manned)			6/14	0.01500				
Dimethyl furan	(Unmanned)							0/10	
	(Manned)							3/14	0.00033
Isopropyl ether	(Unmanned)			0/11		6/10	0.02200		
	(Manned)			1/14	0.00020	13/14	0.16000		

TABLE IX (contd.)

Compound by chemical class		Arnold		Lockheed		Melpar		Von Karman	
		Freq.*	Conc. (mg./m.³)	Freq.	Conc. (mg./m.³)	Freq.	Conc. (mg./m.³)	Freq.	Conc. (mg./m.³)
1,4-Dimethoxybenzene	(Unmanned)							0/10	
	(Manned)							1/14	0.00370
Benzyl ether	(Unmanned)							0/10	
	(Manned)							1/14	0.00670
Halogen derivatives of aromatic and cyclic hydrocarbons									
Chlorobenzene	(Unmanned)					3/10	0.00330	0/10	
	(Manned)					2/14	0.00220	0/14	
Halogen derivatives of ethane									
1,2-Dichloroethane	(Unmanned)	5/11	0.03700			9/10	0.07300	6/10	0.17000
	(Manned)	11/14	0.25000			6/14	0.03250	2/14	0.00260
1,1-Dichloroethane	(Unmanned)	7/11	0.02600						
	(Manned)	13/14	0.09500						
Pentafluoroethane	(Unmanned)							0/10	
	(Manned)							7/14	0.02300
Methyl chloroform	(Unmanned)	1/11	0.05000			6/10	0.00470	1/10	0.01900
	(Manned)	0/14				3/14	0.00076	5/14	0.05800
Freon 114	(Unmanned)							5/10	0.00530
	(Manned)							11/14	0.28000
Freon 113	(Unmanned)							0/10	
	(Manned)							1/14	0.02000
Halogen derivatives of ethylene									
Vinyl chloride	(Unmanned)	2/11	0.02100			7/10	0.03000	0/10	
	(Manned)	0/14				9/14	0.01000	0/14	
1,1-Dichloroethylene	(Unmanned)	4/11	0.08000					7/10	0.03100
	(Manned)	3/14	0.00210					0/14	
Trichloroethylene	(Unmanned)	0/11		8/11	0.19000	3/10	0.00110	9/10	0.13000
	(Manned)	1/14	0.03800	4/14	0.07300	3/14	0.00810	9/14	0.08300
Perchloroethylene	(Unmanned)	8/11	36.00000			0/10		0/10	
	(Manned)	8/14	0.04400			4/14	0.02900	0/14	

TABLE IX (contd.)

Compound by chemical class		Arnold		Lockheed		Melpar		Von Karman	
		Freq.*	Conc. (mg./m.^{3})	Freq.	Conc. (mg./m.^{3})	Freq.	Conc. (mg./m.^{3})	Freq.	Conc. (mg./m.^{3})
Halogen derivatives of methane									
Methyl chloride	(Unmanned)	0/11		2/11	0.00420	0/10		0/10	
	(Manned)	0/14		6/14	0.01100	0/14		0/14	
Methylene chloride	(Unmanned)	6/11	0.03000	1/11	0.01100	5/10	0.01000	6/10	0.10000
	(Manned)	3/14	0.19000	0/14		1/14	0.03100	11/14	0.05000
Freon 22	(Unmanned)	0/11		5/11	0.00810	0/10		0/10	
	(Manned)	0/14		3/14	0.00120	0/14		0/14	
Chloroform	(Unmanned)	4/11	0.07800	0/11		6/10	0.11000	2/10	0.02800
	(Manned)	3/14	510.00000	0/14		13/14	1.90000	11/14	0.88000
Freon 11	(Unmanned)	10/11	11.00000	10/11	1.80000	7/10	0.03700	10/10	0.18000
	(Manned)	13/14	10.00000	12/14	1.50000	10/14	1.33000	12/14	0.30000
Carbon tetrachloride	(Unmanned)	8/11	0.16000	0/11		0/10		4/10	0.08300
	(Manned)	3/14	0.05300	0/14		0/14		2/14	0.00010
Indoles									
Skatole	(Unmanned)	0/11		0/11		0/10		0/10	
	(Manned)	0/14		0/14		0/14		8/14	0.05900
Ketones									
Acetone	(Unmanned)	10/11	0.45000	11/11	0.04500	9/10	0.11000	10/10	0.41000
	(Manned)	14/14	7.50000	13/14	0.01600	13/14	0.33000	14/14	1.30000
Methyl ethyl ketone	(Unmanned)	4/11	0.01800	0/11		10/10	0.02600	7/10	0.24000
	(Manned)	13/14	0.02300	0/14		14/14	0.01600	12/14	0.01600
Methyl isobutyl ketone	(Unmanned)	0/11		0/11		0/10		5/10	0.05700
	(Manned)	0/14		0/14		0/14		4/14	0.00100
Naphthenes									
Cyclopropane	(Unmanned)			2/11	0.01100			0/10	
	(Manned)			3/14	0.00970			0/14	
Cyclohexane	(Unmanned)			6/11	0.03300			2/10	0.00038
	(Manned)			8/14	0.00600			5/14	0.00067

TABLE IX (contd.)

Compound by chemical class		Arnold		Lockheed		Melpar		Von Karman	
		Freq.*	Conc. (mg./m.^{3})	Freq.	Conc. (mg./m.^{3})	Freq.	Conc. (mg./m.^{3})	Freq.	Conc. (mg./m.^{3})
Methyl cyclohexane	(Unmanned)			7/11	0.00200			3/10	0.08000
	(Manned)			1/14	0.00150			5/14	0.12000
Dimethyl cyclopentane	(Unmanned)			0/11				5/10	0.05400
	(Manned)			0/14				1/14	0.00030
Dimethyl cyclohexane	(Unmanned)							6/10	0.02400
	(Manned)							8/14	0.02600
Indene	(Unmanned)							4/10	0.01200
	(Manned)							9/14	0.01700
Decalin	(Unmanned)							0/10	
	(Manned)							8/14	0.03800
Decalin isomers	(Unmanned)							0/10	
	(Manned)							4/14	0.00190
Paraffins									
Methane	(Unmanned)	0/11				0/10		0/10	
	(Manned)	0/14				3/14	0.02800	2/14	0.00100
Ethane	(Unmanned)	1/11	0.01400	7/11	0.02700	0/10		0/10	
	(Manned)	0/14		6/14	0.00260	5/14	0.05200	2/14	0.00100
Propane	(Unmanned)	1/11	0.01800	11/11	0.02000				
	(Manned)	0/14		11/14	0.05000				
Butane	(Unmanned)			10/11	0.01200				
	(Manned)			11/14	0.05300				
Isobutane	(Unmanned)			11/11	0.02000				
	(Manned)			8/14	0.00970				
Pentane	(Unmanned)			10/11	0.00190			5/10	0.00800
	(Manned)			7/14	0.00330			10/14	0.03300
Isopentane	(Unmanned)							9/10	0.01800
	(Manned)							12/14	0.01500
Hexane	(Unmanned)	9/11	0.23000	10/11	0.01900	8/10	0.03700	3/10	0.01600
	(Manned)	12/14	0.02380	1/14	0.00024	7/14	0.76000	3/14	0.02200

TABLE IX (contd.)

Compound by chemical class		Arnold		Lockheed		Melpar		Von Karman	
		Freq.*	Conc. (mg./m.^{3})	Freq.	Conc. (mg./m.^{3})	Freq.	Conc. (mg./m.^{3})	Freq.	Conc. (mg./m.^{3})
2,2-Dimethyl butane	(Unmanned)							7/10	0.00620
	(Manned)							8/14	0.07000
2,3-Dimethyl butane	(Unmanned)							8/10	0.01400
	(Manned)							7/14	0.29000
Heptane	(Unmanned)	6/11	0.09600	9/11	0.02000	0/10		3/10	0.02700
	(Manned)	8/14	0.02200	5/14	0.00380	1/14	0.00230	0/14	
Iso-octane	(Unmanned)							1/10	0.24000
	(Manned)							1/14	0.00069
Sulfides									
Hydrogen sulfide	(Unmanned)	9/11	0.73000						
	(Manned)	8/14	0.96000						
Sulfur compounds									
Propyl mercaptan	(Unmanned)							0/10	
	(Manned)							1/14	0.12000
Olefins									
Ethylene	(Unmanned)	0/11		4/11	0.00100			0/10	
	(Manned)	4/14	0.02700	1/14	0.00270				
Propylene	(Unmanned)			10/11	0.02400			4/10	0.00230
	(Manned)			7/14	0.02400			8/14	0.23000
1-Butene	(Unmanned)			8/11	0.01000				
	(Manned)			10/14	0.01500				
2-Butene (cis)	(Unmanned)			0/11					
	(Manned)			3/14	0.08200				
2-Butene (trans)	(Unmanned)			1/11	0.00110				
	(Manned)			5/14	0.00580				

TABLE IX (contd.)

Compound by chemical class		Arnold		Lockheed		Melpar		Von Karman	
		Freq.*	Conc. (mg./m.^{3})	Freq.	Conc. (mg./m.^{3})	Freq.	Conc. (mg./m.^{3})	Freq.	Conc. (mg./m.^{3})
Isobutylene	(Unmanned)			9/11	0.01000				
	(Manned)			8/14	0.00800				
1-Pentene	(Unmanned)			0/11					
	(Manned)			1/14	0.00350				
Halogen derivatives of higher aliphatic hydrocarbons									
Propyl chloride	(Unmanned)					10/10	0.02000		
	(Manned)					6/14	0.05400		
Diolefins									
Allene	(Unmanned)			0/11					
	(Manned)			3/14	0.01400				
1,3-Butadiene	(Unmanned)			1/11	0.00310				
	(Manned)			4/14	0.00700				
Isoprene	(Unmanned)			0/11				1/10	0.00490
	(Manned)			0/14				13/14	0.65000
Acetylenes									
Acetylene	(Unmanned)			6/11	0.02300				
	(Manned)			1/14	0.00110				
Propyne	(Unmanned)			1/11	0.00180				
	(Manned)			1/14	0.00640				
Cyclo-olefins									
Cyclohexene	(Unmanned)			3/11	0.00400				
	(Manned)			9/14	0.00600				

*Denominator of fraction indicates the number of samples of test cell atmosphere, and numerator indicates positive identification of the corresponding compound.

TABLE X

Compounds identified only during the manned portion of the experiment

Compound by chemical class	Frequency*	Reporting contractor
Organic acids		
Propionic acid	3/14	Von Karman Center
Valeric acid	5/14	Von Karman Center
Aldehydes		
Butyraldehyde	4/14	Von Karman Center
Aromatic hydrocarbons		
Mesitylene	5/15	Von Karman Center
Esters		
Methyl n-butyrate	4/14	Von Karman Center
Butyl acetate	5/14	Von Karman Center
Ethers		
Furan	8/14	Von Karman Center
1,4-Dimethoxybenzene	1/14	Von Karman Center
Benzyl ether	1/14	Von Karman Center
Dimethyl furan	3/14	Von Karman Center
Halogen derivatives of ethane		
Freon 113	1/14	Von Karman Center
Pentafluoroethane	7/14	Von Karman Center
Indole		
Skatole	8/14	Von Karman Center
Naphthenes		
Decalin	8/14	Von Karman Center
Decalin isomers	4/14	Von Karman Center
Paraffins		
Methane	2/14	Von Karman Center
	3/14	Melpar, Inc.
Sulfur compounds		
Propyl mercaptan	1/14	Von Karman Center
Olefins		
2-Butene (cis)	3/14	Lockheed Missiles and Space Company
1-Pentene	1/14	Von Karman Center
Diolefins		
Allene	3/14	Lockheed Missiles and Space Company
Amine		
Methyl amine	1/14	Von Karman Center

*Denominator of fraction indicates the number of samples of test cell atmosphere, and numerator indicates positive identification of the corresponding compound.

TABLE XI

Compounds identified by Arnold Engineering and Development Center

Compound by chemical class	Unmanned	Manned
Inorganic acids		
Hydrogen fluoride	X	X
Carbon dioxide	X	X
Alcohols		
Methyl alcohol	X	X
Ethyl alcohol	X	X
Isopropyl alcohol	X	X
Aldehydes		
Acetaldehyde	X	X
Aromatic hydrocarbons		
Benzene	X	X
Toluene	X	X
Xylene	X	X
Ethers		
Tetrahydrofuran	X	X
Halogen derivatives of ethane		
1,2-Dichlorethane	X	X
1,1-Dichloroethane	X	X
Methyl chloroform	X	
Halogen derivatives of ethylene		
Vinyl chloride	X	
1,1-Dichloroethylene	X	X
Trichloroethylene		X
Perchloroethylene	X	X
Halogen derivatives of methane		
Methylene chloride	X	X
Chloroform	X	X
Freon 11	X	X
Carbon tetrachloride	X	X
Ketones		
Acetone	X	X
Methyl ethyl ketone	X	X
Paraffins		
Ethane	X	
Propane	X	
Hexane	X	X
Heptane	X	X
Sulfides		
Hydrogen sulfide	X	X
Olefins		
Ethylene		X

TABLE XII

Compounds identified by Lockheed Missiles and Space Company

Compound by chemical class	Unmanned	Manned
Inorganic acids		
Carbon dioxide	X	X
Alcohols		
Ethyl alcohol	X	
Allyl alcohol	X	X
n-Propyl alcohol	X	X
Aromatic hydrocarbons		
Benzene	X	X
Toluene	X	X
Xylene	X	X
Ethyl benzene	X	X
Esters		
Methyl acetate		X
Ethers		
Ethyl ether	X	X
Dioxane	X	X
Isopropyl ether		X
Halogen derivatives of methane		
Methyl chloride	X	X
Methylene chloride	X	
Freon 22	X	X
Freon 11	X	X
Halogen derivatives of ethylene		
Trichloroethylene	X	X
Ketones		
Acetone	X	X
Naphthenes		
Cyclopropane	X	X
Cyclohexane	X	X
Methyl cyclohexane	X	X
Paraffins		
Ethane	X	X
Propane	X	X
Butane	X	X
Isobutane	X	X
Pentane	X	X
Heptane	X	X
Hexane	X	X
Olefins		
Ethylene	X	X
Propylene	X	X
1-Butene	X	X
2-Butene (cis)		X
2-Butene (trans)	X	X
Isobutylene	X	X
1-Pentene		X
Diolefins		
Allene		X
1,3-Butadiene	X	X
Acetylenes		
Acetylene	X	X
Propyne	X	X
Cyclo-olefins		
Cyclohexene	X	X

TABLE XIII

Compounds identified by Melpar, Inc.

Compound by chemical class	Unmanned	Manned
Inorganic acids		
Carbon dioxide	X	X
Alcohols		
Methyl alcohol	X	X
Ethyl alcohol	X	X
Allyl alcohol	X	X
Isopropyl alcohol		X
Butyl alcohol	X	X
Isobutyl alcohol	X	X
Aromatic hydrocarbons		
Toluene	X	X
Xylene	X	X
Esters		
Ethyl acetate	X	X
n-Propyl acetate	X	X
Ethers		
Ethyl ether	X	X
Isopropyl ether	X	X
Halogen derivatives of aromatic and cyclic hydrocarbons		
Chlorobenzene	X	X
Halogen derivatives of ethane		
1,2-Dichloroethane	X	X
Methyl chloroform	X	X
Halogen derivatives of ethylene		
Vinyl chloride	X	X
Trichloroethylene	X	X
Perchloroethylene		X
Halogen derivatives of methane		
Methylene chloride		X
Chloroform	X	X
Freon 11	X	X
Ketones		
Acetone	X	X
Methyl ethyl ketone	X	X
Paraffins		
Methane		X
Ethane		X
Hexane	X	X
Heptane		X
Halogen derivatives of higher aliphatic hydrocarbons		
Propyl chloride	X	X

TABLE XIV

Compounds identified by Von Karman Center

Compound by chemical class	Unmanned	Manned
Inorganic acids		
Carbon dioxide	X	X
Organic acids		
Acetic acid	X	X
Propionic acid		X
Valeric acid		X
Alcohols		
Methyl alcohol	X	X
Ethyl alcohol	X	X
Allyl alcohol	X	
Isopropyl alcohol	X	X
Isobutyl alcohol	X	X
Aldehydes		
Acetaldehyde	X	X
Butyraldehyde		X
Aromatic hydrocarbons		
Benzene	X	X
Toluene	X	X
Styrene	X	
o-Xylene	X	X
Ethyl benzene	X	X
Pseudocumene	X	X
Mesitylene		X
Naphthalene	X	X
Tetramethylbenzene	X	X
Methyl naphthalene	X	X
Dimethyl naphthalene	X	X
Esters		
Methyl acetate	X	X
Ethyl formate	X	X
Ethyl acetate	X	X
Methyl n-butyrate		X
Butyl acetate		X
Ethers		
Furan		X
Tetrahydrofuran	X	X
Ethyl ether	X	X
Methyl furan	X	X
Dimethyl furan		X
1,4-Dimethoxybenzene		X
Benzyl ether		X
Halogen derivatives of ethane		
1,2-Dichloroethane	X	X
Pentafluoroethane		X
Methyl chloroform	X	X

TABLE XIV (contd.)

Compound by chemical class	Unmanned	Manned
Freon 114	X	X
Freon 113		X
Halogen derivatives of ethylene		
1,1-Dichloroethylene	X	
Trichloroethylene	X	X
Halogen derivatives of methane		
Methylene chloride	X	X
Chloroform	X	X
Freon 11	X	X
Carbon tetrachloride	X	X
Indoles		
Skatole		X
Ketones		
Acetone	X	X
Methyl ethyl ketone	X	X
Methyl isobutyl ketone	X	X
Naphthenes		
Cyclohexane	X	X
Methyl cyclohexane	X	X
Dimethyl cyclopentane	X	X
Dimethyl cyclohexane	X	X
Indene	X	X
Decalin		X
Decalin isomers		X
Paraffins		
Methane		X
Ethane		X
Pentane	X	X
Isopentane	X	X
Hexane	X	X
2,2-Dimethyl butane	X	X
2,3-Dimethyl butane	X	X
Heptane	X	
Iso-octane	X	X
Sulfur compounds		
Propyl mercaptan		X
Olefins		
Ethylene		X
Propylene	X	X
Diolefins		
Isoprene	X	X
Amines		
Methyl amine		X

TABLE XV

Carbon monoxide concentration in milligrams per cubic meter (mg./m.³) (.9127) = p.p.m.

4 to 29 June 1965	Time	Lira 300	Lira 300 (daily av.)	IR-7
		Unmanned		
4			2.0	
5			0.0	
6			0.0	
7			3.9	
8			1.9	
9			0.0	
10			4.6	
11			4.9	
12			0.5	
13			0.0	
14			1.8	
		Manned		
15			5.2	
	1530	6.9		1.1
16			4.5	
	0600	2.3		3.4
	1745	5.7		4.1
17			9.7	
	0730	5.7		3.2
	1515	13.7		7.1
18			8.5	
	0830	8.4		8.4
	1600	3.9		9.2
19			9.8	
	0845	6.9		9.7
	1645	13.7		9.8
20			12.0	
	0815	13.2		11.2
	1900	11.4		11.2
21			12.2	
	0745	13.7		13.1
	1815	12.6		12.0
22			14.9	
	0930	13.7		13.1
	1915	17.2		9.8
23			15.5	
	1015	13.7		14.8
	1830	14.9		13.2
24			18.0	
	0845	17.2		17.3
	1600	20.6		16.8
25			17.6	
	0930	20.6		17.6
	1630	16.0		16.3

TABLE XV (contd.)

4 to 29 June 1965	Time	Lira 300	Lira 300 (daily av.)	IR-7
26			17.7	
	0830	17.7		16.8
	2130	18.9		16.9
27			20.3	
	0845	20.6		19.1
	1540	20.6		18.7
28			22.7	
	0716	20.6		16.8
	1245	20.6		17.5
29			24.6	

The methane concentration in milligrams per cubic meter, as determined by the MicroTek 1600, is presented in table XVI. Methane exhibited a trend similar to carbon monoxide, increasing from a low concentration of 25.5 mg./m.^{3} on the second day of the experiment to a high concentration of 79.7 mg./m.^{3} on the tenth day. Initially, the rate of increase was rapid, but decreased with experiment duration.

The gas loss into the annular space of the test cell and that amount removed for analytical procedures averaged 5.9 liters per hour during the unmanned portion of the experiment and 12.8 liters per hour during the manned portion. The increase in leak rate was the result of a rupture of the door gasket. During the entire experiment, 5,635 liters leaked from the test cell and 4,397 liters of nitrogen were added. Since the amount of nitrogen added was considered to be 80% of the gas loss, calculations indicated that the total loss should have been 5,496 liters, a value in good agreement with the measured leak.

Pre- and postexperimental physical examinations of the four subjects were normal. Hematologic studies, likewise, manifested no abnormality. Results of liver function studies are presented in table XVII. Subject 84 showed a rise in total serum bilirubin from 0.4 to 1.1 mg. % and a decrease in the albumin/globulin ratio from 2.9 to 1.3. Subject 86 exhibited a rise in total serum bilirubin from

TABLE XVI

Methane concentration in milligrams per cubic meter during the manned portion of the experiment (mg./m.^{3}) (1.53) = p.p.m.

16 to 29 June 1965	Time	Concentration
16	1400	20.9
	1900	30.1
17	0900	29.4
	1300	29.4
18	0830	35.3
	1630	33.4
19	1000	29.4
20	1515	44.5
21	0800	53.0
22	1600	57.6
24	0900	62.0
	1300	62.8
25	0900	64.5
	1640	74.9
26	0100	84.6
	2230	67.9
27	0900	72.7
	1000	76.5
	1520	70.6
	1630	70.6
29	0500	75.9
	0530	68.7
	0600	75.2

1.05 to 1.5 mg. %. Other measurements of liver function revealed no further deviations. Subjects 84 and 86 developed presyncopal symptoms during postexperimental tilt-table studies. Subjects 85 and 87 showed a decline in work capacity by 4 and 5 minutes, respectively, on postexperimental treadmill tests. Other studies, including electrocardiograms, chest roentgenograms, and electroencephalograms, were normal.

V. DISCUSSION

Comparison of compounds reported in this study with those compounds previously reported as being present in spacecraft, submarines, and simulators indicates that many

contaminants of low concentration were not previously detected. The collection and analytical technics previously used appear to have been specific only to those easily identified compounds—i.e., strong IR sorption, specific mass spectrum patterns, and high gas chromatographic specificity and sensitivity.

It was necessary to extrapolate the data obtained from this experiment in order to estimate a potential contaminant level for use in any closed system. The loss and gain of contaminants from the system through leakage and the known addition of compounds were considered. It must be noted, however, that this was a clinically controlled study with a minimum of equipment and no "flight hardware" within the test cell. Differences in individuals, personal activity, food, and many other variables will add to or delete compounds identified in this study.

The determination of the concentration in milligrams per cubic meter of a compound in the test cell, considering zero leak from the test cell and no addition of the compound from the supply gas, may contribute information concerning the production rate of the compound.

To correct the concentration, it was necessary to determine the total gas lost from the test cell, the apparent leak by the removal of compounds from the atmosphere by the cryogenic trapping systems, and the amount to be subtracted owing to the contribution of compounds from the supply gases (tables VII and VIII). In applying these corrections, the study was divided into time periods which were related to the effective leak, oxygen and nitrogen addition, and the sample cylinder set by contractor. The information thus acquired and tabulated is presented in tables XVIII to XXI.

It was also necessary in the calculation to determine the free volume of the test cell. The volume was determined when conditions were static and when the subjects were within the test cell and was found to be 27.45 $m.^3$

Results of these manipulations are graphically displayed in appendixes I to IV. It should be noted that the abscissas of the graphs express periods of collection as delineated on tables XVIII to XXI. Statistical analysis of the corrected concentrations did not yield any significant data owing to the inconsistency among contractors.

TABLE XVII

Liver function studies

Subject No.	Period	Bilirubin (mg. %)	SGOT units*	SGPT units*	Alkaline phosphatase units†	Albumin/globulin	Percent BSP retention (45 min.)
84	Pre-	0.4	24	13	13.6	2.9	0
	Post-	1.1	22	17	9.9	1.3	2
85	Pre-	0.8	24	16	6.1	1.3	0
	Post-	0.9	18	20	5.9	1.3	0
86	Pre-	1.05	26	16	7.7	1.3	1
	Post-	1.5	19	13	9.5	1.3	2
87	Pre-	0.6	28	22	5.1	1.7	1
	Post-	0.9	20	14	4.1	1.7	2

*Sigma-Frankel units.

†King-Armstrong units.

TABLE XVIII

Required data for calculation of zero leak concentration of compounds reported by Arnold Engineering and Development Center

Period of collection	Time	4 to 28 June 1965	Effective leak ($m.^3$)	Sample No.	Amount of gas added ($m.^3$) Oxygen	Amount of gas added ($m.^3$) Nitrogen
			Unmanned			
1	2230-0500	4	0.372	6-4-2BA		
2	0500-1900	5	0.784			
3	1900-0500	5	0.583	6-5-2AA		
4	0500-0630	6	0.001			
5	0630-1600	6	0.653	6-6-1BA		
6	1600-0600	6	0.629			
7	0600-1600	7	0.636	6-7-1BA		
8	1600-0600	7	0.599			
9	0600-1600	8	0.625	6-8-1BA		
10	1600-1700	8	1.243			0.037
11	1700-0300	9	0.592	6-9-2AA		
12	0300-0600	10	−0.003			
13	0600-1600	10	0.623	6-10-1BA		
14	1600-1800	10	1.403		0.159	0.120
15	1800-0500	11	0.783	6-11-2BA		0.187
16	0500-1830	12	0.903			0.268
17	1830-0430	12	0.721	6-12-2AA	0.004	
18	0430-1800	13	0.872			
19	1800-0400	13	0.727	6-13-2AA	0.004	0.141
20	0400-0600	14	0.008			
21	0600-1700	14	0.809	6-14-1BA		0.202
22	1700-1830	14	1.529		1.359	0.439
			Manned			
23	1830-0500	15	0.593	6-15-2BA	1.276	0.130
24	0500-0600	16	0.007		0.053	
25	0600-1700	16	0.886	6-16-1BA	0.689	0.503
26	1700-0600	16	0.911		1.740	
27	0600-1630	17	0.731	6-17-1BA	0.631	
28	1630-1800	17	1.655		2.314	0.319
29	1800-0400	18	0.752	6-18-2AA	1.035	
30	0400-1800	19	0.908		2.224	0.288
31	1800-0500	19	0.614	6-19-2BA	1.254	
32	0500-1730	20	0.561		1.074	0.390
33	1730-0330	20	0.761	6-20-2AA	1.070	
34	0330-1800	21	0.906		1.180	0.338
35	1800-0400	21	0.774	6-21-2AA	1.174	
36	0400-1800	22	0.914		1.140	
37	1800-0430	22	0.703	6-22-2BA	1.219	0.212
38	0430-0600	23	0.015		0.162	
39	0600-1700	23	0.779	6-23-1BA	0.897	
40	1700-0600	23	0.741		1.425	0.157
41	0600-1700	24	0.845	6-24-1BA	0.839	
42	1700-1800	24	1.597		2.270	0.276
43	1800-0400	25	0.682	6-25-2AA	1.392	
44	0400-1830	26	0.835		1.264	
45	1830-0430	26	0.650	6-26-2BA	1.031	0.082
46	0430-1800	27	0.796		0.838	0.097
47	1800-0400	27	0.620	6-27-2BA	0.988	
48	0400-0630	28	0.012		0.184	
49	0630-1730	28	0.769	6-28-1BA	0.759	

TABLE XIX

Required data for calculation of zero leak concentration of compounds reported by Lockheed Missiles and Space Company

Period of collection	Time	4 to 28 June 1965	Effective leak (m.³)	Sample No.	Amount of gas added (m.³)	
					Oxygen	Nitrogen
			Unmanned			
1	2230-0500	4	0.372	6-4-2AL		
2	0500-1900	5	0.784			
3	1900-0700	5	0.632	6-5-2BL		
4	0700-1730	6	0.603			
5	1730-0400	6	0.628	6-6-2AL		
6	0400-1800	7	0.646			
7	1800-0400	7	0.592	6-7-2AL		
8	0400-1800	8	0.638			0.037
9	1800-0400	8	0.597	6-8-2AL		
10	0400-0600	9	0.005			
11	0600-1600	9	0.609	6-9-1BL		
12	1600-1700	9	1.231			
13	1700-0500	10	0.658	6-10-2AL	0.125	
14	0500-1800	11	0.737		0.034	0.120
15	1800-0500	11	0.783	6-11-2AL		0.187
16	0500-1800	12	0.888			0.268
17	1800-0430	12	0.741	6-12-2BL	0.004	
18	0430-0600	13	0.007			
19	0600-1700	13	0.845	6-13-1BM		
20	1700-1800	13	1.582		0.004	0.342
21	1800-0430	14	0.685	6-14-2BL		
22	0430-1830	15	0.825		1.359	0.439
			Manned			
23	1830-0500	15	0.593	6-15-2AL	1.425	0.130
24	0500-1800	16	0.927		0.983	0.503
25	1800-0400	16	0.852	6-16-2AL	1.416	
26	0400-1800	17	0.795		0.839	
27	1800-0400	17	0.716	6-17-2BL	1.139	
28	0400-0600	18	0.029		0.246	
29	0600-1700	18	0.849	6-18-1BL	0.770	0.319
30	1700-1800	18	1.694		3.282	0.288
31	1800-2330	19	0.379	6-19-2AL	0.603	
32	2330-0630	19	0.255		0.787	
33	0630-1700	20	0.526	6-20-1BL	0.938	0.390
34	1700-0600	20	0.814		1.345	
35	0600-1800	21	0.869	6-21-1BL	0.905	0.338
36	1800-0600	21	0.809		1.388	
37	0600-1730	22	0.869	6-22-1BL	0.809	
38	1730-1800	22	1.526		2.515	0.212
39	1800-0400	23	0.713	6-23-2BL	0.957	0.157
40	0400-1800	24	0.885		1.126	
41	1800-0400	24	0.679	6-24-2AL	1.130	
42	0400-0600	25	0.033		0.090	
43	0600-1700	25	0.858	6-25-1BL	0.771	0.276
44	1700-0630	25	0.719		1.753	
45	0630-1730	26	0.787	6-26-1BL	0.978	
46	1730-0600	26	0.683		1.337	0.082
47	0600-1800	27	0.785	6-27-1BL	0.634	0.097
48	1800-1800	27	1.395		1.984	
49	1800-0400	28	0.652	6-28-2AL	1.161	0.212

TABLE XX

Required data for calculation of zero leak concentration of compounds reported by Melpar, Inc.

Period of collection	Time	5 to 28 June 1965	Effective leak ($m.^3$)	Sample No.	Amount of gas added ($m.^3$)	
					Oxygen	Nitrogen
			Unmanned			
1	0600-1900	5	0.788	6-5-1AM		
2	0900-0630	5	0.582			
3	0630-1600	6	0.653	6-6-1AM		
4	1600-0600	6	0.629			
5	0600-1600	7	0.636	6-7-1AM		
6	1600-0600	7	0.599			
7	0600-1600	8	0.625	6-8-1AM		
8	1600-0600	8	0.623			
9	0600-1600	9	0.609	6-9-1AM		0.037
10	1600-0600	9	0.601			
11	0600-1600	10	0.623	6-10-1AM		
12	1600-0600	10	0.666		0.125	
13	0600-1800	11	0.737	6-11-1AM	0.034	0.120
14	1800-0630	11	0.793			0.187
15	0630-1830	12	0.893	6-12-1AM		0.268
16	1830-0600	12	0.729		0.004	
17	0600-1700	13	0.845	6-13-1AL		
18	1700-0600	13	0.755		0.004	0.141
19	0600-1700	14	0.809	6-14-1AM		0.202
20	1700-0600	14	0.711			
			Manned			
21	0600-1730	15	0.821	6-15-1AM	1.216	0.439
22	1730-0600	15	0.597		1.478	0.130
23	0600-1700	16	0.886	6-16-1AM	0.689	0.503
24	1700-0600	16	0.911		1.740	
25	0600-1630	17	0.731	6-17-1AM	0.631	
26	1630-0600	17	0.784		1.521	
27	0600-1700	18	0.849	6-18-1AM	0.770	0.319
28	1700-0600	18	0.807		1.243	
29	0600-1700	19	0.875	6-19-1AM	1.998	0.288
30	1700-0630	19	0.647		1.431	
31	0630-1700	20	0.526	6-20-1AM	0.938	0.390
32	1700-0600	20	0.814		1.345	
33	0600-1730	21	0.875	6-21-1AM	0.792	0.338
34	1730-0600	21	0.830		1.501	
35	0600-1700	22	0.841	6-22-1AM	0.809	
36	1700-0600	22	0.738		1.498	0.212
37	0600-1700	23	0.779	6-23-1AM	0.897	
38	1700-0600	23	0.741		1.425	0.157
39	0600-1700	24	0.845	6-24-1AM	0.839	
40	1700-0600	24	0.729		1.322	
41	0600-1700	25	0.858	6-25-1AM	0.771	0.276
42	1700-0630	25	0.719		1.753	
43	0630-1730	26	0.787	6-26-1AM	0.978	
44	1730-0600	26	0.683		1.337	0.082
45	0600-1700	27	0.760	6-27-1AM	0.445	0.097
46	1700-0630	27	0.616		1.361	
47	0630-1730	28	0.769	6-28-1AM	0.759	

TABLE XXI

Required data for calculation of zero leak concentration of compounds reported by Von Karman Center

Period of collection	Time	5 to 28 June 1965	Effective leak ($m.^3$)	Sample No.	Amount of gas added ($m.^3$)	
					Oxygen	Nitrogen
			Unmanned			
1	0600-1900	5	0.787	6-5-1BV		
2	1900-1730	5	1.241			
3	1730-0400	6	0.628	6-6-2BV		
4	0400-1800	7	0.646			
5	1800-0400	7	0.592	6-7-2BV		
6	0400-1800	8	0.638			0.037
7	1800-0400	8	0.597	6-8-2BV		
8	0400-1700	9	0.625			
9	1700-0300	9	0.592	6-9-2BV		
10	0300-1700	10	0.628			
11	1700-0500	10	0.658	6-10-2BV	0.125	
12	0500-0600	11	0.001			
13	0600-1700	11	0.714	6-11-1BV	0.034	0.120
14	1700-0630	11	0.816			0.187
15	0630-1800	12	0.877	6-12-1BV		0.265
16	1800-1800	12	1.613		0.004	
17	1800-0400	13	0.727	6-13-2BV	0.004	0.141
18	0400-1800	14	0.836			0.202
19	1800-0430	14	0.685	6-14-2AV		
20	0430-0600	15	0.007			
			Manned			
21	0600-1730	15	0.821	6-15-1BV	1.210	0.439
22	1730-1800	15	1.517		2.408	0.632
23	1800-0400	16	0.852	6-16-2BV	1.416	
24	0400-1800	17	0.795		0.839	
25	1800-0400	17	0.716	6-17-2AV	1.139	
26	0400-1800	18	0.882		1.039	0.319
27	1800-0400	18	0.752	6-18-2BV	1.035	
28	0400-0600	19	0.021		0.185	
29	0600-1700	19	0.875	6-19-1BV	1.998	0.289
30	1700-1730	19	1.188		2.369	0.390
31	1730-0330	20	0.761	6-20-2BV	1.070	
32	0330-1800	21	0.906		1.180	0.338
33	1800-0400	21	0.774	6-21-2BV	1.174	
34	0400-1800	22	0.914		1.140	
35	1800-0430	22	0.703	6-22-2AV	1.219	0.212
36	0430-1800	23	0.813		1.180	
37	1800-0400	23	0.713	6-23-2AV	0.957	0.157
38	0400-1800	24	0.885		1.126	
39	1800-0400	24	0.679	6-24-2BV	1.130	
40	0400-1800	25	0.901		1.038	0.276
41	1800-0400	25	0.682	6-25-2BV	1.392	
42	0400-1830	26	0.835		1.264	
43	1830-0430	26	0.650	6-26-2AV	1.031	0.082
44	0430-1800	27	0.796		0.838	0.097
45	1800-0400	27	0.620	6-27-2AV	1.177	
46	0400-1800	28	0.775		0.996	
47	1800-0400	28	0.652	6-28-2BV	1.161	0.212

The graphic representations contained in the appendixes, while not statistically significant, may be visually interpreted. Interpretations by the authors have been made and are presented in table XXII. This table, categorized by chemical class, indicates the general shape of the time concentration graphs of the four contractors during both the unmanned and the manned portions of the experiment. A study of this table results in the following general observations.

Inorganic acids

Carbon dioxide, which has been included in this study even though it is a well-known product of man, provides a key for the interpretation of the data. During the unmanned portion of the experiment, the four contract analysis groups indicated a steady state or a decreasing concentration; however, all four groups subsequently indicated an increase, which demonstrated the production of the compound as the result of the inclusion of man into the test cell. Hydrogen fluoride also increased during the manned portion of the experiment. Inspection of table XXII indicates an increase in most fluoride-containing compounds during the manned portion of the experiment. An analysis of the analytical technics of Arnold showed that hydrogen fluoride could have been a misinterpretation of the mass spectrum fragmentation patterns (15).

Organic acids

The organic acids reported appear to have been generated by man. Acetic acid appeared in the unmanned portion; however, acetic anhydride is present in a silicone adhesive used extensively for the installation of seals in the test cell. The silicone adhesive was used by the subjects in an attempt to repair a defective door seal when they first entered the test cell, which was indicated by a rise in the concentration of acetic acid. This concentration subsequently decreased and may be attributed to reaction with the lithium hydroxide canisters for sorption of carbon dioxide. The acetic acid showed a final increase in concentration, which may be indicative of production by man.

Alcohols

Three of the contractors reported methyl alcohol. Arnold and Melpar reported methyl alcohol during both the unmanned and manned portions with increasing concentrations during the manned portion of the experiment. Von Karman reported isolated occurrences only during the manned portion of the experiment; however, sufficient evidence is presented to establish methyl alcohol as a product of man.

Ethyl alcohol was reported by all four contractors. Lockheed reported ethyl alcohol only during the unmanned portion of the experiment, while Arnold reported it only during the manned portion of the experiment. Melpar and Von Karman reported ethyl alcohol during both the unmanned and manned portions of the experiment. There was a decrease in the concentration during the unmanned portion of the experiment. An increase during the manned portion of the experiment indicated that ethyl alcohol was produced by man.

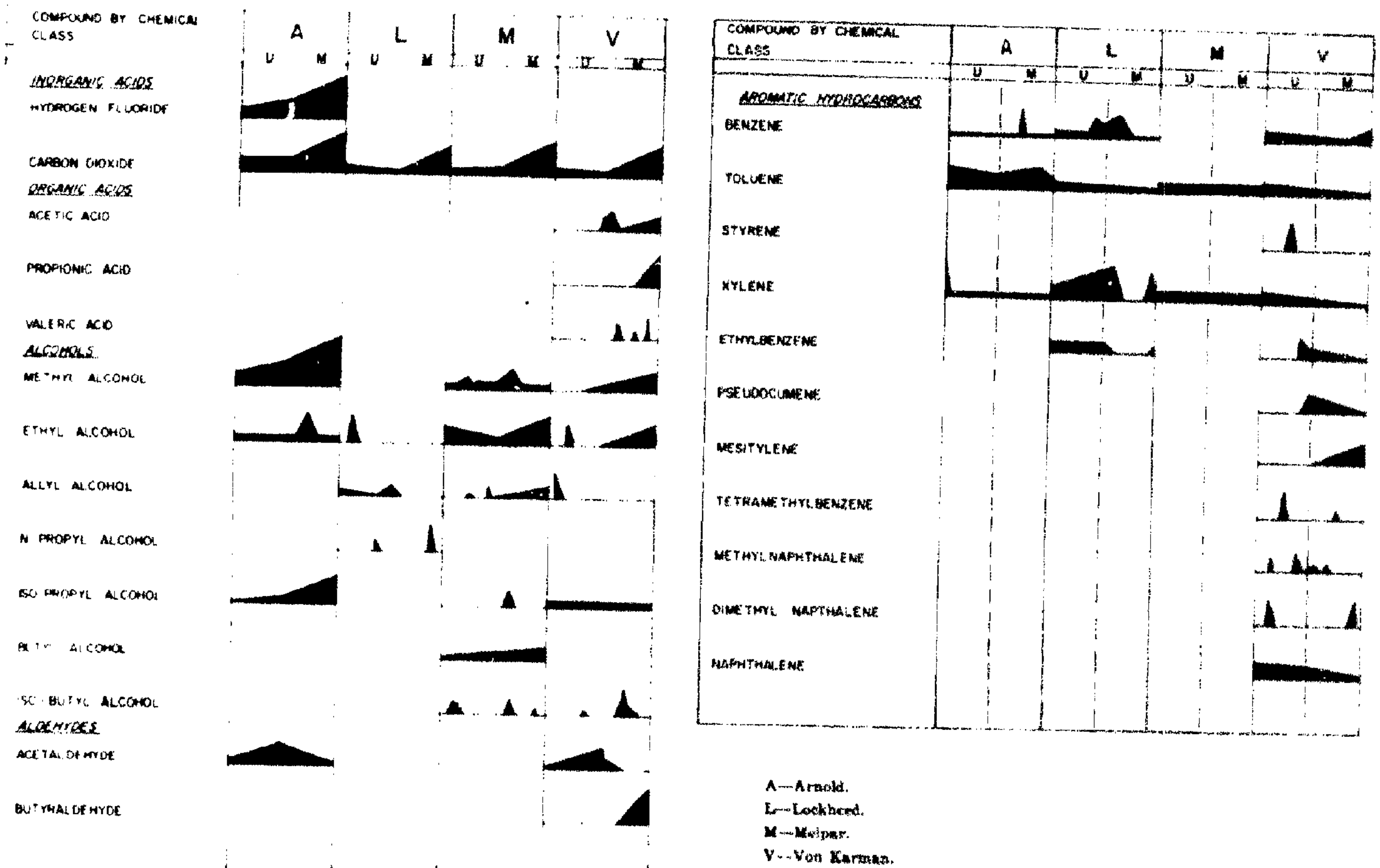
Arnold indicated an increase of isopropyl alcohol after man entered the test cell; however, Melpar showed only scattered peaks, while Von Karman reported a steady state. Evidence still is sufficient, it is felt, to assume that isopropyl alcohol is a by-product from the inclusion of man into the system. Butyl alcohol was reported only by Melpar, and the general shape of the graph indicated a constant generation during the experiment in both the unmanned and manned portions.

Aldehydes

Graphical representations by Arnold and Von Karman showed an increase in acetaldehyde concentration during the unmanned portion of the experiment with a subsequent decrease in the concentration after man entered the system. This decrease, which occurred after the addition of man into the system, may indicate the conversion of the material by man. The removal of acetaldehyde by the more extensive use of lithium hydroxide absorbent or the increased quantities of condensate water present may also have contributed to the decrease. Butyraldehyde showed an increase in

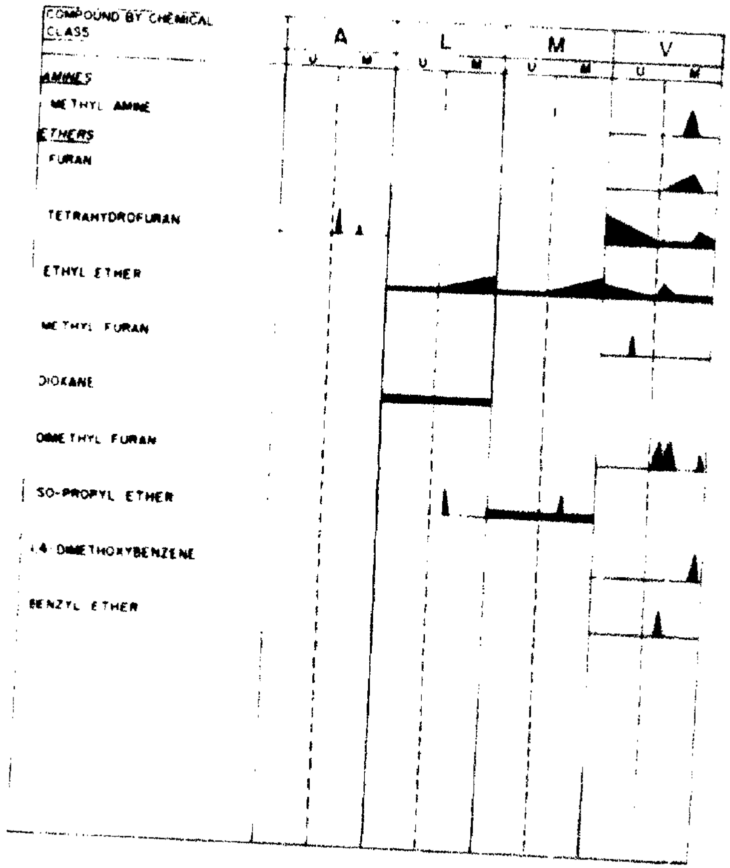
TABLE XXII

A summary of graphic representations of data contained in the appendixes



A—Arnold.
L—Lockheed.
M—Melpar.
V—Von Karman.
U—unmanned; M—manned.

TABLE XXII (contd.)



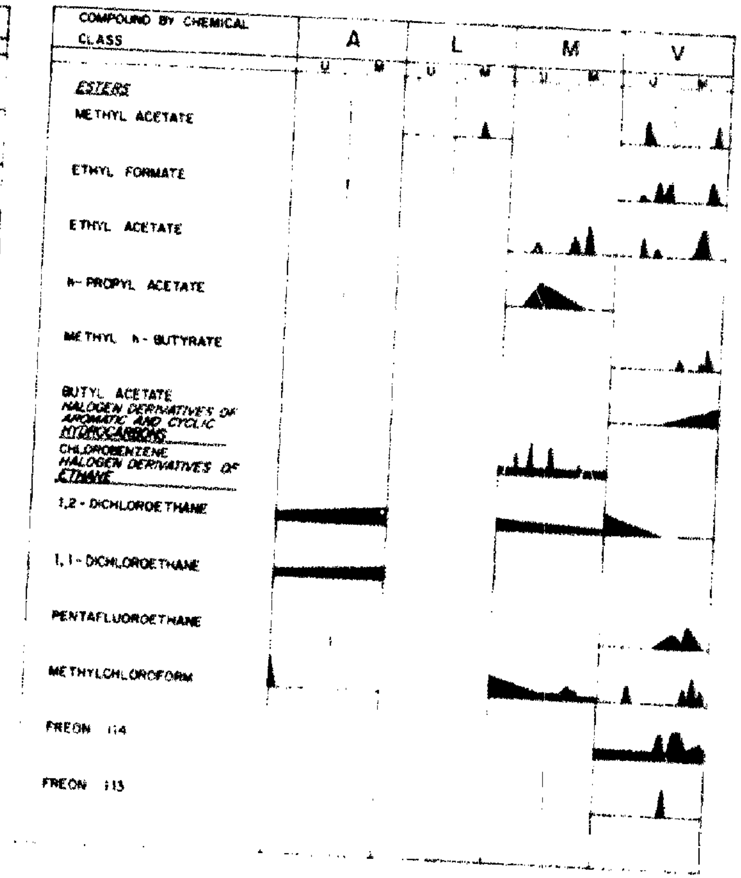


TABLE XXII (contd.)

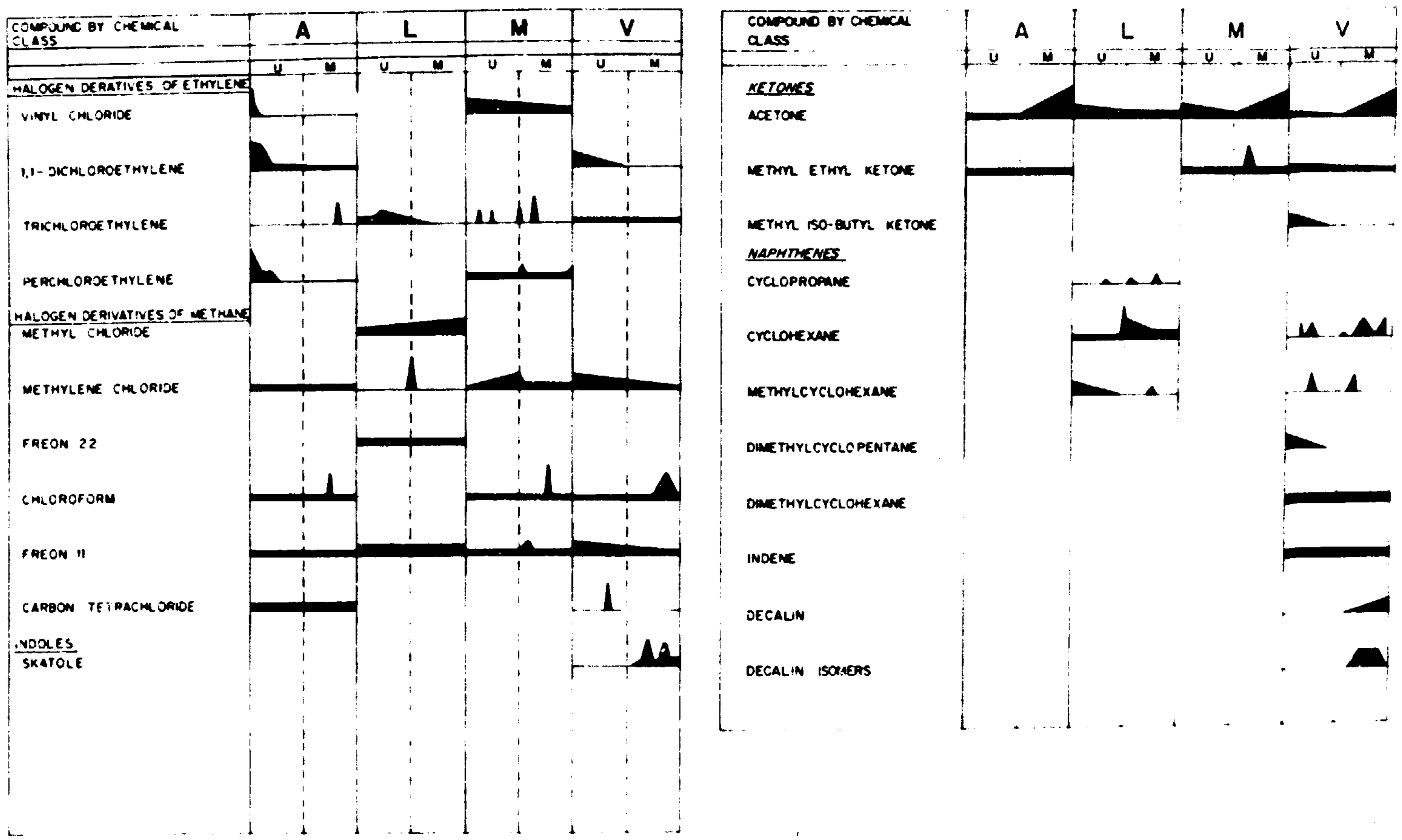
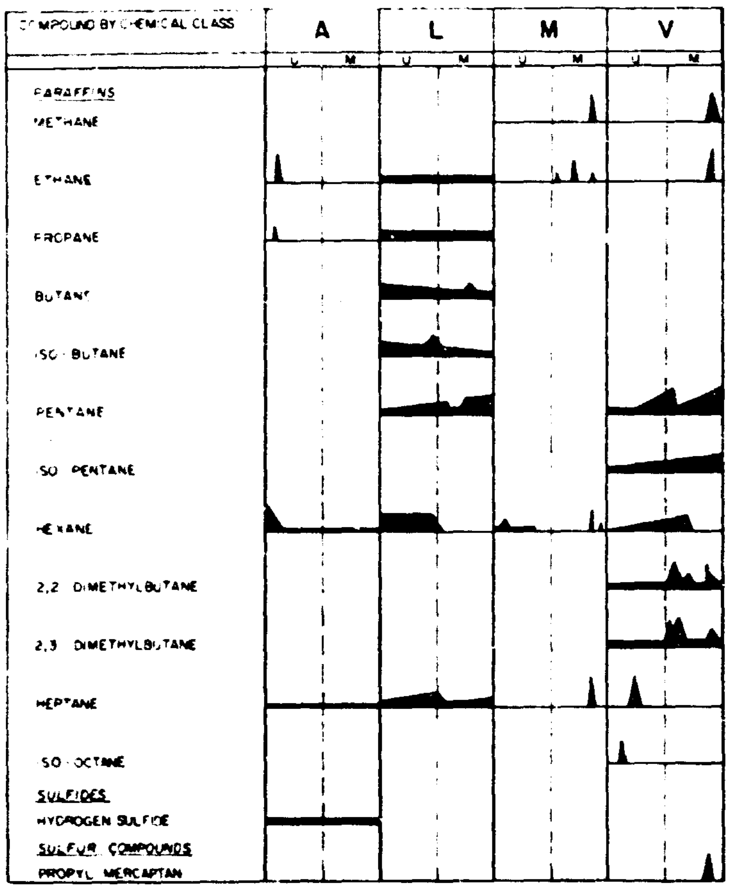
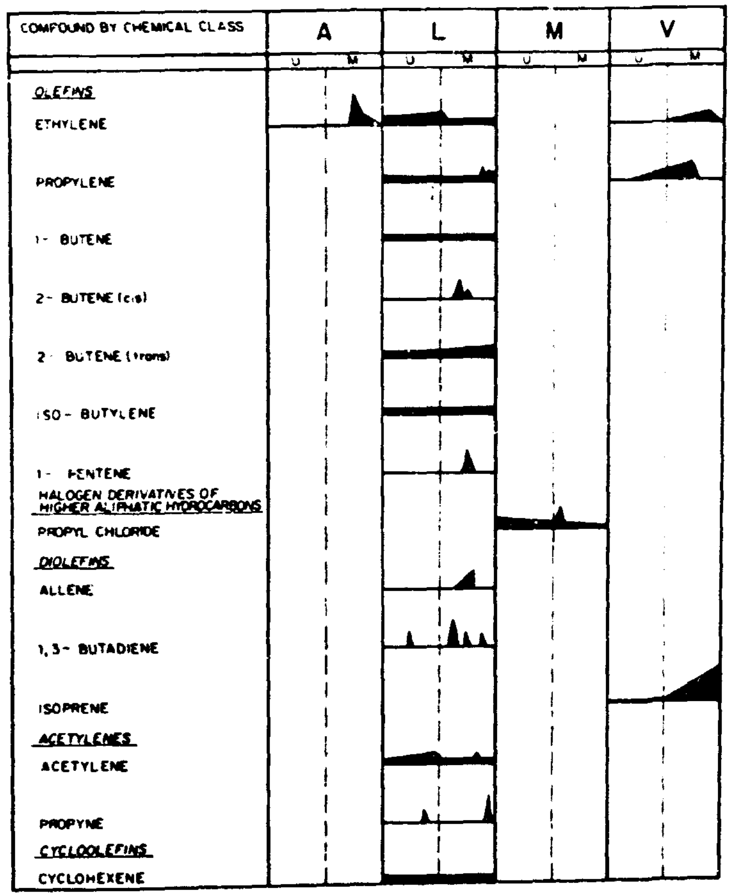


TABLE XXII (contd.)





the manned portion of the experiment and was reported only by Von Karman.

Aromatic hydrocarbons

The graphical representations of benzene indicated a steady state during the experiment with isolated excursions in concentration. Benzene was reported by Arnold, Lockheed, and Von Karman. Toluene has an essentially steady-state concentration, as illustrated by the graphical representation of the Melpar data. A decrease in concentration is shown by the graphs of Lockheed and Von Karman. The graphical representation of Arnold indicated an increase in concentration for a short duration after the inclusion of man into the system, followed by a decrease. The decrease in all cases demonstrated nonproduction of toluene by man. The graphical representations of xylene are similar to those of toluene. Arnold showed a decrease from an early high concentration to a steady state. The Lockheed data indicated a rise in concentration until man entered the system, after which the concentration decreased and disappeared and subsequently reappeared toward the end of the experiment. The data of Melpar demonstrated a steady-state condition. The data of Von Karman showed a decrease during the entire experiment. Benzene, toluene, and xylene are solvents common to the chamber and would be off-gassed in varying amounts during the experiment, as indicated by the data. In addition, some removal might be expected from the inclusion of man into the system by his detoxification of the compounds. This is shown by the data of Von Karman concerning ethyl benzene, pseudocumene, naphthalene, and methyl naphthalene. The graphical presentation of mesitylene showed the appearance of the compound with the inclusion of man and an increase during the manned portion of the experiment, as reported by Von Karman

Amines

Methyl amine was reported only by Von Karman as a peak during the manned portion of the experiment. This observation is true of many of the 21 compounds that were reported only during the manned portion of the experiment and is either directly or indirectly due to man's existence in this sealed environment. Only 3 of the 21 compounds were reported by contractors other than Von Karman.

Ethers

From the graphical representations, the data of Von Karman indicated an initial increase in the concentration of furan with the inclusion of man into the system, followed by a decrease in concentration. The rise in concentration of the compound is the result of the inclusion of man into the system. Tetrahydrofuran, however, was present during the unmanned portion of the experiment and showed a decrease until it reached a steady-state condition during the first portion of the manned phase. Tetrahydrofuran was used for washing the trapping cylinders and may have been introduced into the analysis in this manner.

Ethyl ether was shown to increase during the manned portion of the experiment from the graphical representations of the data of Lockheed and Melpar. Von Karman, however, showed a high at the beginning of both the unmanned and manned phases of the experiment with a subsequent decrease in concentration in later portions of the unmanned and manned phases.

Dimethyl furan, 1,4-dimethoxybenzene, and benzyl ether appeared as points in the manned portion of the experiment as reported by Von Karman and were included in the list of 21 compounds reported only during the manned portion of the study. The other ethers were reported in a steady state or as scattered points during the unmanned portion of the experiment.

Esters

n-Propyl acetate, as shown by Melpar, reached an initial high concentration during the unmanned portion of the experiment and steadily decreased throughout the experiment. This decrease does not appear to have been affected by the inclusion of man into the system. The data from Von Karman for methyl n-butyrate and butyl acetate indicated an increase in concentration during the manned phase.

Halogen derivatives of hydrocarbons

The halogen derivatives of hydrocarbons are commonly found in compressed gases. The compounds could have been in low concentrations and not detected in the supply gas analyses and, therefore, not subtracted during the calculation of the graphical representations The halogen derivatives of hydrocarbons are also common solvents used in the preparation of many of the materials used in the construction of the test cell. This class of compounds could have been sorbed on the wall of the test cell before the initiation of the experiment.

Chlorobenzene as reported by Melpar remained in an essentially steady-state condition with occasional excursions. 1,2-Dichloroethane indicated a steady increase in concentration as reported by Arnold; however, a decrease was reported by Melpar and Von Karman. These data indicated a material not affected by the inclusion of man into the system but were indicative of the variance of analytical technic.

Pentafluoroethane and Freon 113 are compounds reported by Von Karman only during the manned portion of the experiment. It is possible that they occur in low concentration in either the supply gas or the test cell and did not reach detectable concentration until the manned phase of the experiment. The pentafluoroethane may have originated from the Teflon diaphragms of the air sample circulation pumps as entrapped material or degradation products.

Chloroform was indicated as in a steady-state concentration by Arnold, Melpar, and Von Karman. It is interesting to note that one excursion in concentration was reported by the three contractors and that these observations were made about the same time. Chloroform was also used as a cylinder washing material by one contractor, and the excursion may have occurred from incomplete removal of the material from the sample cylinder, allowing some of the chloroform to be transported into the test cell. This emphasizes the importance of degassing a trapping cylinder set.

Freon 11 is a common material found in supply gases and was most likely sorbed in some quantity to the surfaces within the test cell. It was reported in an essentially steady-state concentration by Arnold and Lockheed. Melpar reported the compound in an essentially steady state with an excursion in concentration at the beginning of the manned portion of the study. Von Karman reported a continuous decrease in concentration during the duration of the experiment.

Indoles

Skatole was reported by Von Karman during the manned phase of the experiment; however, visual inspection of the graphical representation in both appendix IV and table XXII shows that the concentration increased with the inclusion of man into the system. Skatole is an outgassing product of fecal material.

Ketones

Acetone is a common solvent that is used in many assemblies and operations associated with the test cell construction. All four analysis groups reported acetone during the unmanned portion of the experiment. Arnold reported acetone as in a steady-state concentration during the unmanned phase. Lockheed, Melpar, and Von Karman reported a decreasing concentration during the unmanned portion of the experiment. During the manned portion of the experiment an increase in concentration was noted by the four contractors. The increase indicated that, although acetone was present from its use in the construction of the test cell, it is also produced in some quantity by man.

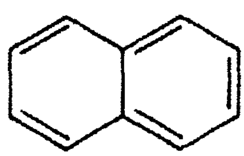
Methyl ethyl ketone, which is commonly used as a paint solvent, was also reported in the test cell. It was described as in a steady-state concentration by Arnold and Melpar. Von Karman described the concentration of methyl ethyl ketone as decreasing for the duration of the entire experiment. A decreasing concentration of methyl isobutyl ketonc during the unmanned portion was also noted by Von Karman.

Naphthenes

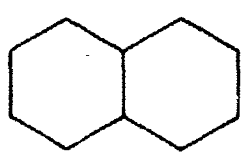
The naphthenes, with the exception of decalin and decalin isomers, are represented by scattered peaks, steady state, or decreasing concentrations during the experiment. Decalin and the isomers of decalin, as indicated by the graphical representations of Von Karman, appear and increase with the inclusion of man into the test cell. The inclusion of man into the test cell results in not only the addition of compounds but also the possible modification of existing contaminants by the formation of new structures. As an example, naphthalene was present as a residual from the mothproofing of blankets used in the test cell. Decalin, which is similar to naphthalene, with the exception that it is a saturated ring structure, appeared in the analysis reports soon after the inclusion of man into the test cell (fig. 6).

Paraffins

Methane is one of the few compounds not concentrated in the passage through the cryogenic trapping system; however, two of the analysis groups, Melpar and Von Karman, did report its occurrence toward the end of the manned phase. Even though not concentrated, the methane concentration had increased sufficiently to allow detection by improved technics of the small quantity entrapped within the cylinder. Ethane was reported as an isolated point during the unmanned portion of the experiment by Arnold and as in a steady state by Lockheed. Melpar and Von Karman reported ethane during the latter part of the manned phase of the experiment. Ethane, like methane, may be added to that list of compounds produced by man.



NAPHTHALENE
$C_{10}H_8$



DECALIN
DECAHYDRO NAPHTHALENE
$C_{10}H_{18}$

FIGURE 6

Structure of naphthalene and decalin.

Propane, butane, isobutane, pentane, and isopentane have concentrations that either are in a steady state or are decreasing or increasing for the duration of the experiment. Hexane, from the graph of Arnold, had a high initial concentration during the unmanned portion of the experiment, which decreased to a steady-state concentration rapidly. Lockheed indicated a similar trend; however, the decrease occurred at the end of the unmanned portion of the experiment. Von Karman indicated a steady increase until after man entered the system. 2,2-Dimethyl butane and 2,3-dimethyl butane, graphically presented from the data of Von Karman, were essentially in a steady state during the unmanned portion of the experiment. The concentration increases in the manned phase and may be attributed to the inclusion of man into the system.

Olefins

Ethylene, from the graphical representations of data from Arnold and Von Karman, increased and decreased in the manned portion of the experiment. The data of Lockheed, however, indicated an increase in the unmanned portion of the study, with a decrease after man entered the test cell.

2-Butene (cis) had isolated peaks during the manned portion of the experiment according to the data of Lockheed. Their data indicated that although 2-butene (trans) was present during the unmanned portion of the experiment, it increased during the manned phase. The 2-butene (trans and cis) may have been produced by the inclusion of man into the

system. 1-Pentene was also present during the manned portion of the experiment, as indicated by the data of Lockheed.

Diolefins

Allene, although only a single point reported by Lockheed during the manned portion of the experiment, was added to the list of materials that were found only during the manned phase.

Isoprene was reported by Von Karman during the entire experiment. The graphical representation, however, showed a rapid increase in concentration after man entered the system. The isoprene may result from the degradation of synthetic rubber or the degassing of the unused monomer; however, the test cell had essentially no changes in operation between the unmanned and manned portions of the study. The increase in isoprene must, therefore, be the result of the addition of man into the test cell.

Of the 97 reported compounds, the following showed a consistent or decreasing concentration: toluene, benzene, xylene, methyl ethyl ketone, Freon 11, and methyl isobutyl ketone. They are indicative of solvents used in the test cell as well as those compounds added by the supply gases. The following are examples of compounds that increased in concentration with the inclusion of man: carbon dioxide, acetic acid, valeric acid, propionic acid, methyl alcohol, ethyl alcohol, isopropyl alcohol, butyraldehyde, mesitylene, methyl amine, methyl n-butyrate, butyl acetate, furan, ethyl ether, dimethyl furan, 1,4-dimethoxybenzene, benzyl ether, skatole, acetone, decalin, decalin isomers, methane, ethane, 2,2-dimethyl butane, 2,3-dimethyl butane, propyl mercaptan, 2-butene (cis), 2-butene (trans), 1-pentene, allene, and isoprene.

The variance for similarly obtained samples and the daily inconsistency among contractors may result in the misinterpretation that man does or does not produce certain compounds. This is graphically depicted in figures 7-10, which portray data for single compounds as determined by the four contractors; the data are plotted on a single graph with an ordinate of 1 + log mg./m.^{3} and an abscissa of experimental days. Further study is required to define the materials produced by man and the production rates of those materials. Many explanations may be proposed for the inconsistency of the data:

1. A variability in obtaining the samples with the cryogenic trapping system.

2. Condensed compounds in the trapping cylinders may alter its thermal characteristics.

3. Interaction between molecular species could increase or decrease the efficiency of the concentration of a material.

4. Operation of the cryogenic trapping systems could have been inconsistent.

5. The degassing of the trapping cylinders (1×10^{-7} mm. Hg at room temperature for 12 hours) may not have been sufficient.

6. Each contractor developed an independent analytical procedure for the analysis.

7. A contractor's variance in analytical technic may have induced error.

8. The material was very low in concentration and, in many cases, sufficient only for gas chromatographic analysis without any verification by other technics.

9. Misinterpretation of gas chromatographic retention times may have contributed to the gas chromatographic errors.

10. A significant number of peaks from the chromatograms, of each analysis and by each contractor, were not identified and are listed in the contractors' reports as "unknown."

Other errors were introduced by the operation of the test cell in controlling pressure, temperature, and water vapor content, and in recharging the lithium hydroxide canisters. Large surface areas were available within the test cell for sorption and desorption of contaminating compounds. Man also adds a variability factor. Man, as a contaminant removal system, may change in efficiency, and contaminant production may be related to physical activity and biochemical needs.

From the data reported in the literature (5, 6, 16), an increase in carbon monoxide concentration during the manned portion of the test was anticipated. Coburn et al. (5) have

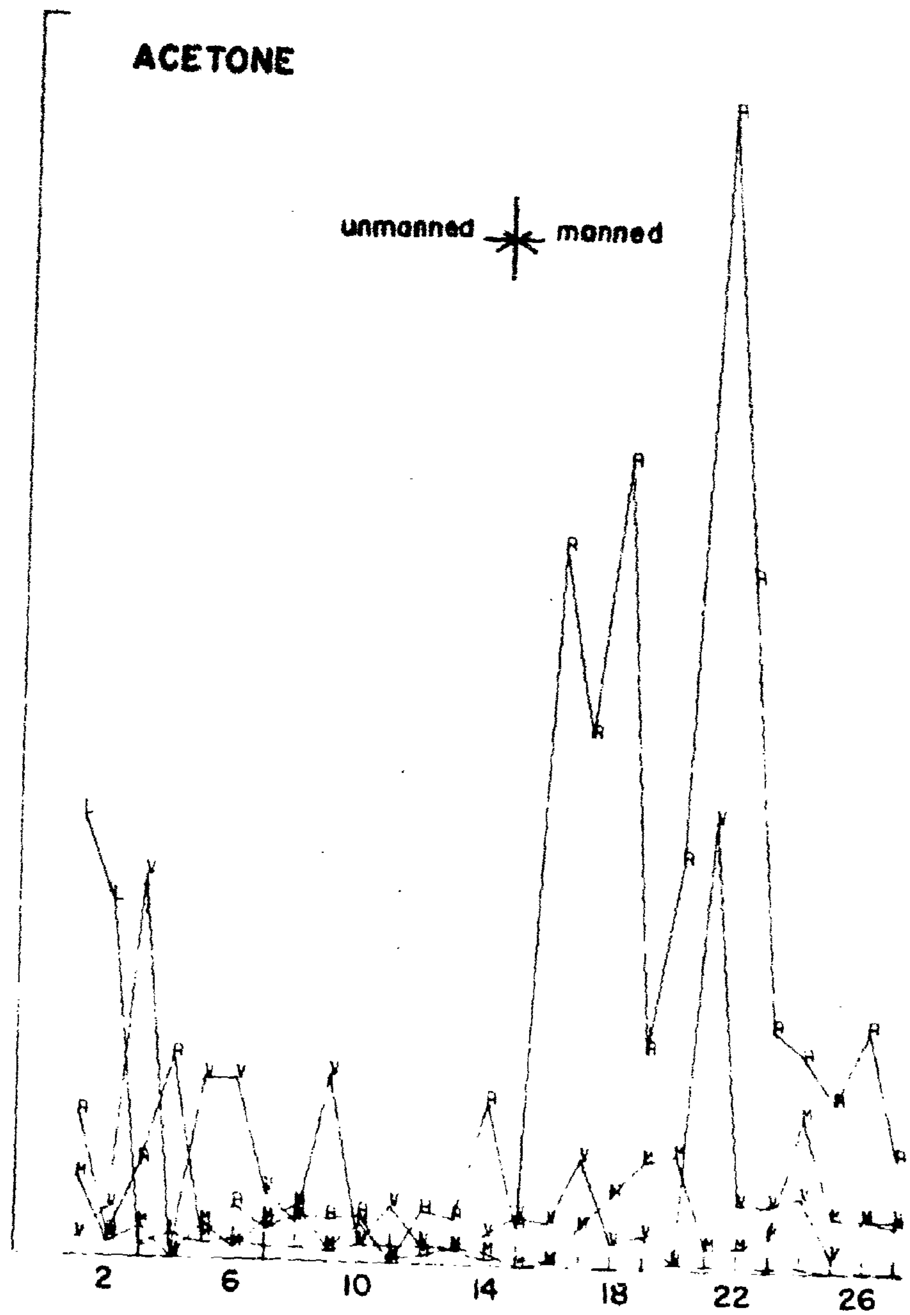


FIGURE 7

Graphic representation of acetone by the four contractors.

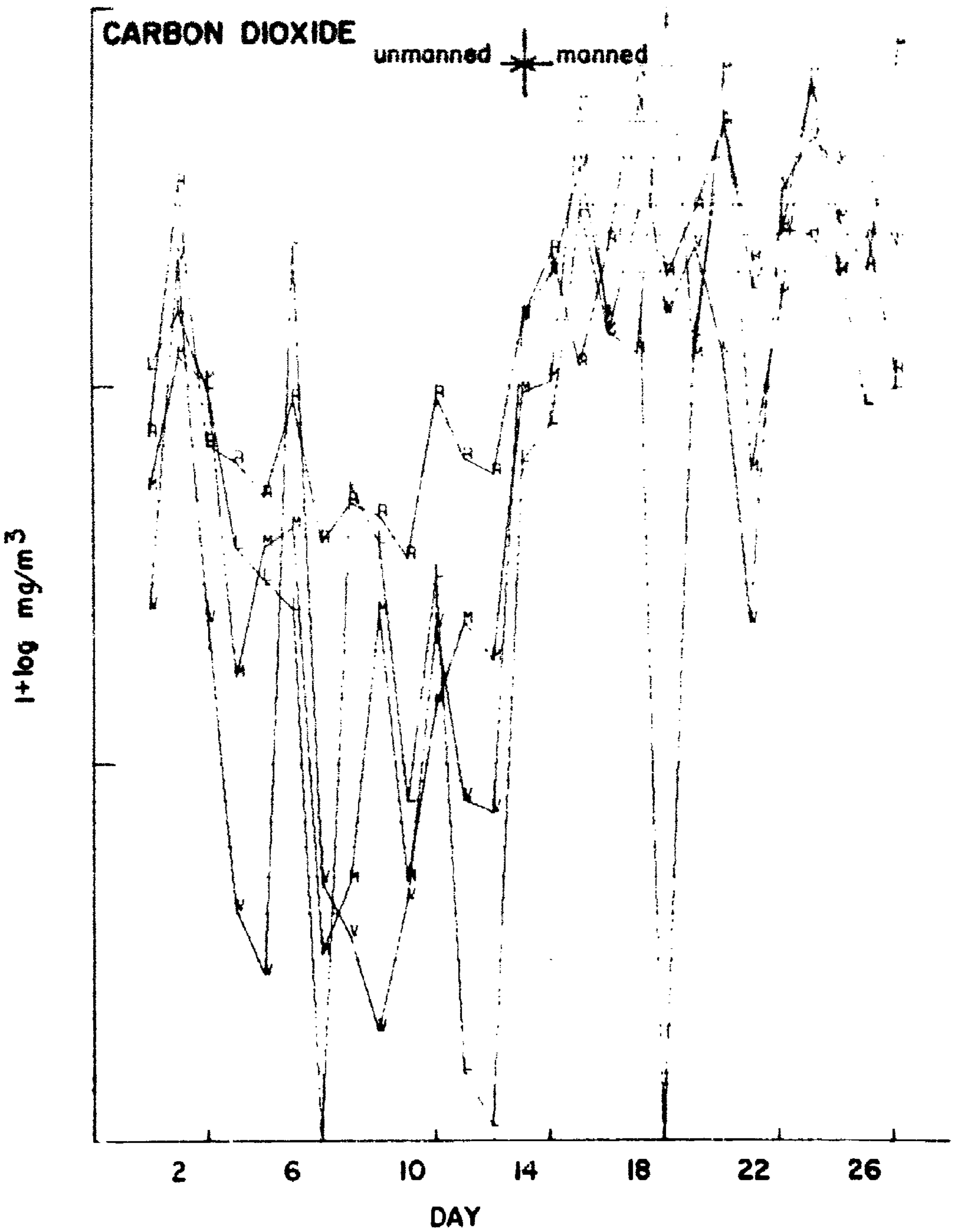


FIGURE 8

Graphic representation of carbon dioxide by the four contractors.

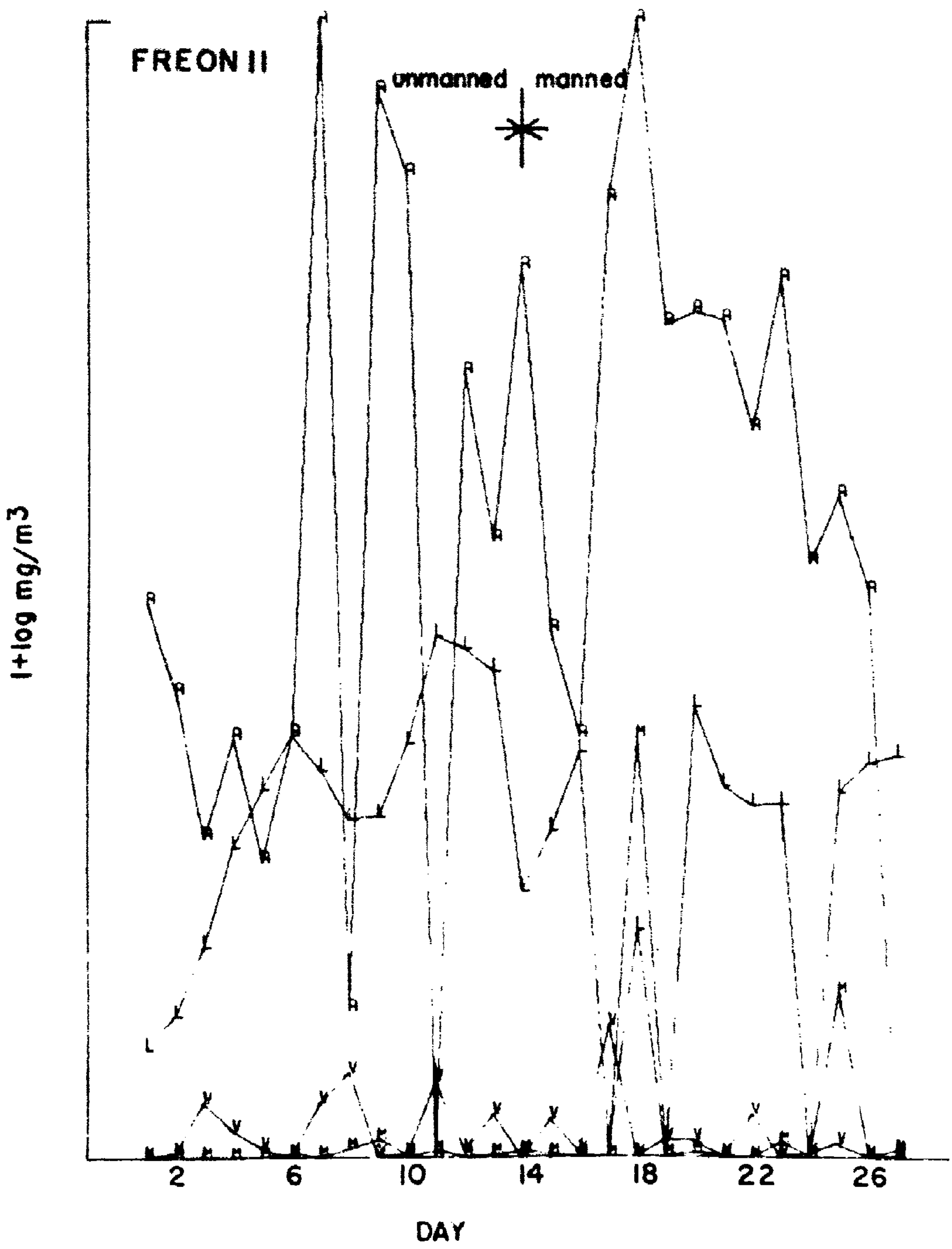


FIGURE 9

Graphic repr sentation of Freon 11 by the four contractors.

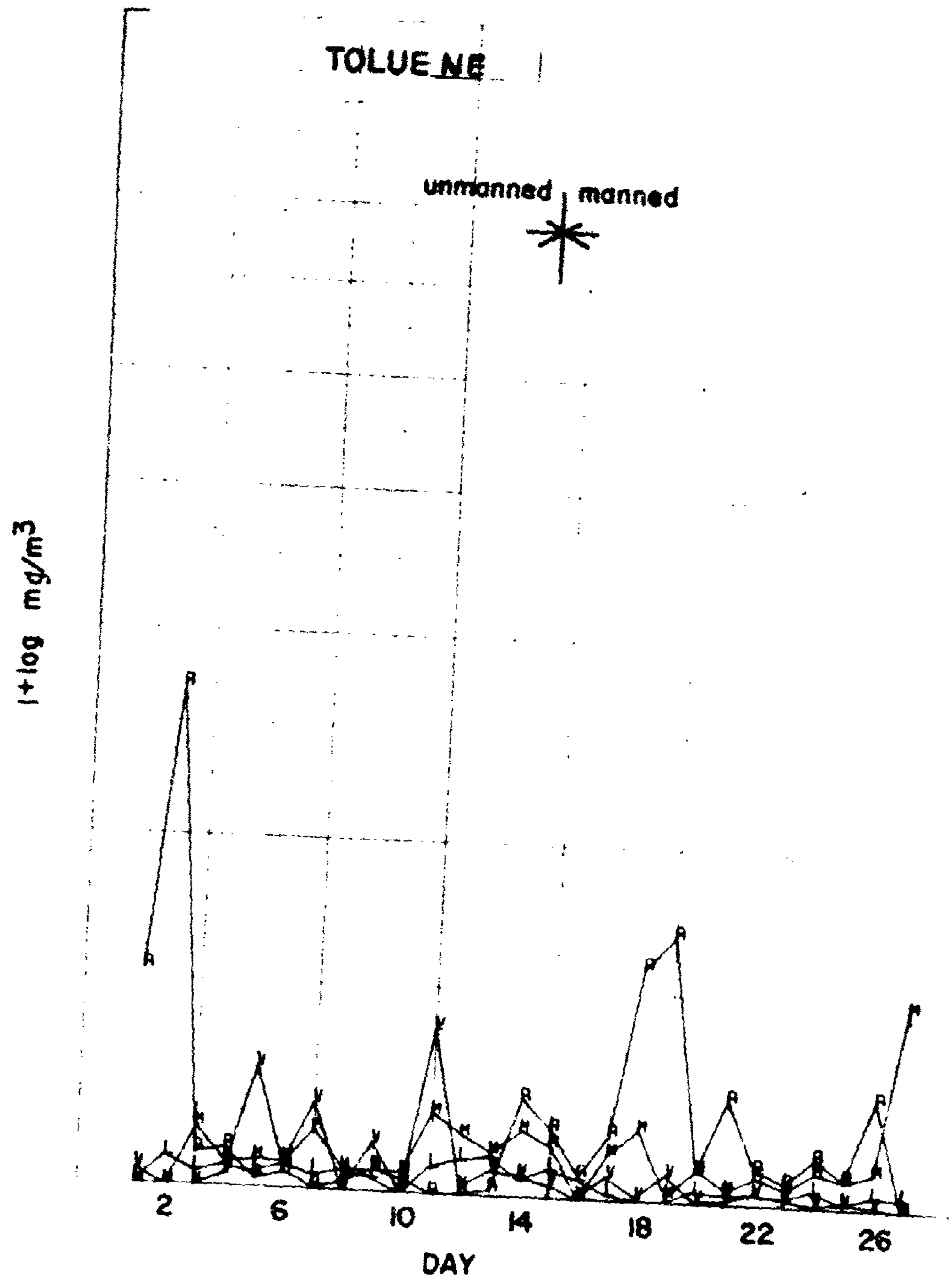


FIGURE 10

Graphic representation of toluene by the four contractors.

reported a CO production rate of 0.42 ml./man/hr., with 0.3 ml./man/hr. being attributed to the normal destruction rate of the erythrocytes, assuming a normal red cell survival of 120 days. The reason for the difference between the reported values is not clear. The additional 0.12 ml./man/hr. is perhaps due to myoglobin degradation or to the washout of CO inspired from the surrounding atmosphere before monitoring CO production. Other investigators (16) have estimated CO production rates as high as 1.0 ml./man/hr.

An evaluation of the analysis, calibration, and collection technics used during this study revealed that the Lira 300 CO data were more accurate than those obtained from the IR-7 (table XXIII). The Lira 300 CO data were corrected to a no-leak condition.

Production rate in this study, corrected for the measured outboard leakage, was estimated to be 0.39 ml./man/hr. at 21.1° C. and 760 mm. Hg or 0.37 ml./man/hr. at 0° C. and 760 mm. Hg. It should be noted that this is only an estimate and is subject to the inaccuracy of knowledge of the absolute leak rate and possible conversion of CO to CO_2 in the test cell or by the human system. Even with these limitations, it is obvious that CO increases significantly in the sealed environment and must be removed for long-term missions.

The methane concentration increased during the manned portion of the experiment (table XXIV). The calculated rate of increase was 2.04 ml./man/hr. based on a no-leak situation. This production rate is in agreement with the published literature (11).

The subjects experienced no obvious ill effects as a result of spending 14 days in the closed environment of the space cabin simulator. Minimal deviations in liver function studies in two subjects were the product of single determinations pre-and postexperimentally. These changes were slight, whereas the bulk of liver function measurements, including BSP retention, was normal. Serum transaminase enzymes, sensitive indicators of acute hepatocellular damage, showed no deviation. Conceivably, an additive effect of numerous atmospheric chemical contaminants, individually in subtoxic concentrations, might exert a deleterious effect on the liver. Cardiovascular deconditioning in the form of decreased work capacity on the treadmill and presyncopal symptoms with tilt-table tests are a function of relative inactivity with confinement and cannot be considered as secondary to atmospheric components (12, 18).

VI. CONCLUSIONS

No significant difference was noted in the average test cell concentration after application of correction for gas leaked from the test cell and subtraction of contaminants added by supply gases.

The interaction of the many contaminant removal systems—such as man, lithium hydroxide, water condensate, walls of the test cell, and materials of construction—modified low level concentrations of contaminants to such an extent as to prevent meaningful production rate determinations. Statistical analysis also provided insufficient information. Methane and carbon monoxide were the only compounds for which production rates could be established.

The concentrations of contaminants during this experiment were such that in unconcentrated samples the dual flame gas chromatograph and the microwave spectrometer did not provide useful information. The concentrations of materials in the unconcentrated samples were below the lower detectable limits of the instrumentation.

The results indicated an effective collection of gaseous contaminants. It is interpreted that the extrapolation of the data to a no-leak condition is valid within the equipment tolerances. The analytical and collection technics at low concentration levels require further investigation and development. It will also be necessary to evaluate the contaminant removal capability of lithium hydroxide and water condensate.

TABLE XXIII

Carbon monoxide data (Lira 300)

Period	4 to 29 June 1965	Time	Actual test cell concentration (mg./m.³)	Calculated no-leak test cell concentration (mg./m.³)
		Unmanned		
1	4	1200	2.0	
2	4-5	1200-1200	1.0*	1.0
3	5	1200	0	
4	5-6	1200-1200	0*	0
5	6	1200	0	
6	6-7	1200-1200	2.0*	2.0
7	7	1200	3.9	
8	7-8	1200-1200	2.9*	2.9
9	8	1200	1.9	
10	8-9	1200-1200	0.9*	1.0
11	9	1200	0	
12	9-10	1200-1200	2.3*	2.3
13	10	1200	4.6	
14	10-11	1200-1200	4.3*	4.3
15	11	1200	4.0	
16	11-12	1200-1200	2.2*	2.3
17	12	1200	0.5	
18	12-13	1200-1200	0.2*	0.3
19	13	1200	0	
20	13-14	1200-1200	0.9*	1.0
21	14	1200	1.8	
22	14-15	1200-1200	3.5*	3.6
		Manned		
23	15	1200	5.2	
24	15-16	1200-1200	4.8*	4.9
25	16	1200	4.5	
26	16-17	1200-1200	7.1*	7.3
27	17	1200	9.7	
28	17-18	1200-1200	9.1*	9.5
29	18	1200	8.5	
30	18-19	1200-1200	9.1*	9.6
31	19	1200	9.8	
32	19-20	1200-1200	10.9*	11.5
33	20	1200	12.0	
34	20-21	1200-1200	12.1*	12.9
35	21	1200	12.2	
36	21-22	1200-1200	13.6*	14.5
37	22	1200	14.9	
38	22-23	1200-1200	15.2*	16.3
39	23	1200	15.5	
40	23-24	1200-1200	16.8*	18.1
41	24	1200	18.0	
42	24-25	1200-1200	17.8*	19.3
43	25	1200	17.6	
44	25-26	1200-1200	17.6*	19.3
45	26	1200	17.7	
46	26-27	1200-1200	19.0*	20.9
47	27	1200	20.3	
48	27-28	1200-1200	21.5*	23.4
49	28	1200	22.7	
50	28-29	1200-1200	23.7*	25.7
51	29	1200	24.6	

*Average value.

TABLE XXIV

Methane concentrations in the test cell during the manned portion of the experiment

Period	16 to 29 June 1965	Time	Actual concentration (mg./m.^{3})	Calculated no-leak concentration (mg./m.^{3})
1	16	1400	20.9	
2	16	1400-1900	25.5*	25.8
3	16	1900	30.1	
4	16-17	1900-0900	29.8*	30.3
5	17	0900	29.4	
6	17	0900-1300	29.4*	30.0
7	17	1300	29.4	
8	17-18	1300-0830	32.4*	33.3
9	18	0830	35.3	
10	18	0830-1630	34.3*	35.4
11	18	1630	33.3	
12	18-19	1630-1000	30.9*	32.2
13	19	1000	29.4	
14	19-20	1000-1515	37.0*	39.0
15	20	1515	44.5	
16	20-21	1515-0800	48.7*	51.2
17	21	0800	53.0	
18	21-22	0800-1600	55.3*	58.8
19	22	1600	57.6	
20	22-24	1600-0900	59.8*	64.3
21	24	0900	62.0	
22	24	0900-1300	62.4*	67.1
23	24	1300	62.8	
24	24-25	1300-0900	63.6*	68.9
25	25	0900	64.5	
26	25	0900-1640	69.7*	75.4
27	25	1640	74.9	
28	25-26	1640-0100	79.7*	85.6
29	26	0100	84.6	
30	26	0100-2230	76.2*	82.8
31	26	2230	67.9	
32	26-27	2230-0900	70.3*	77.5
33	27	0900	72.7	
34	27	0900-1000	74.6*	81.8
35	27	1000	76.5	
36	27	1000-1520	73.6*	80.9
37	27	1520	70.6	
38	27	1520-1630	70.6*	78.5
39	27	1630	70.6	
40	27-29	1630-0500	73.2*	81.1
41	29	0500	75.9	

*Average value.

Of the compounds detected during this study, only carbon monoxide and carbon dioxide required detection and removal; however, this was a clinically controlled investigation. Differences in individuals, physical activity, food, materials of construction, and environmental control systems will add to or delete chemical compounds identified in this report.

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APPENDIX I

A DETAILED STUDY OF CONTAMINANT PRODUCTION IN A SPACE CABIN SIMULATOR AT 760 MM. HG

Graphic Representation of Compounds (Arnold Engineering and Development Center)

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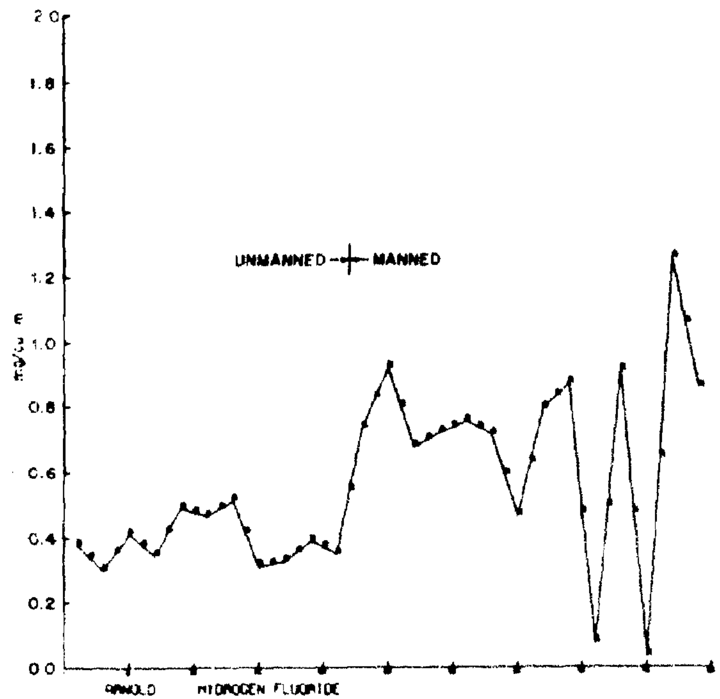
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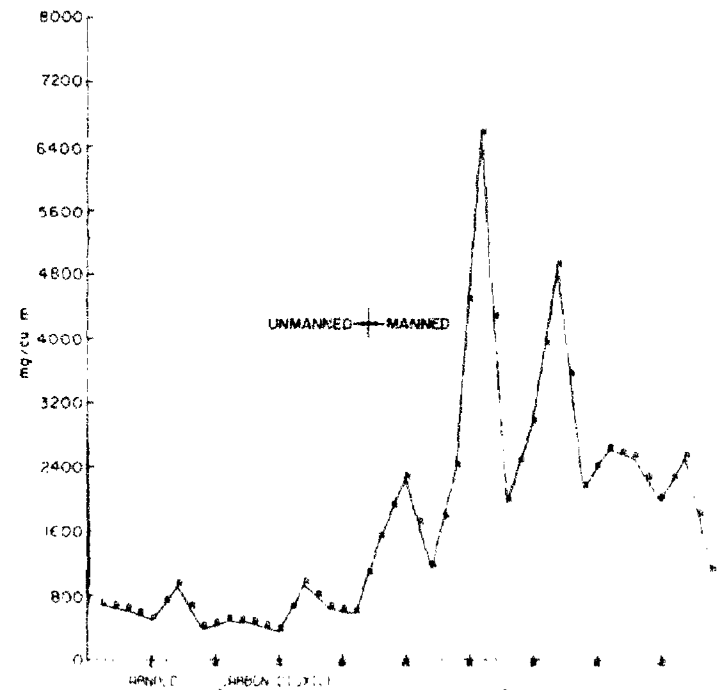
mg/cu m
ARNOLD
HYDROGEN FLUORIDE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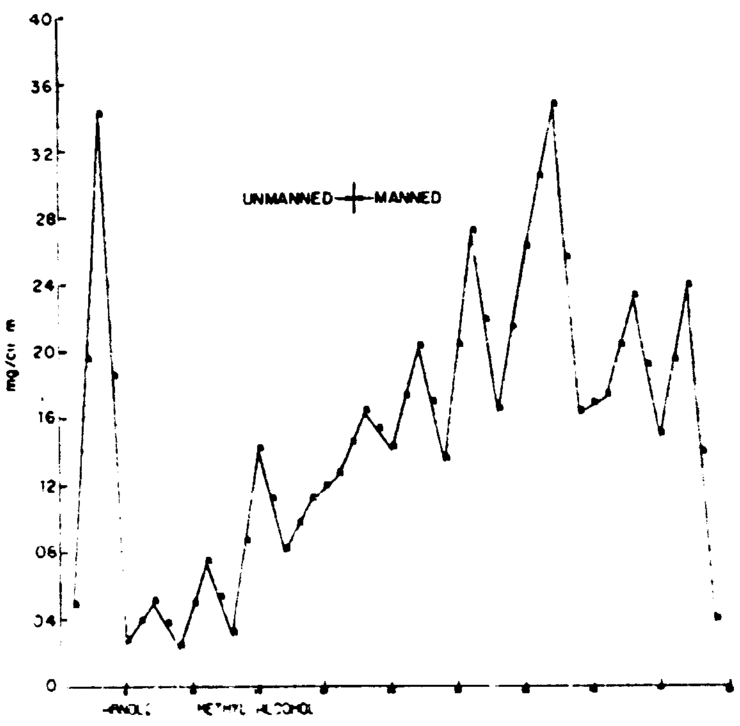
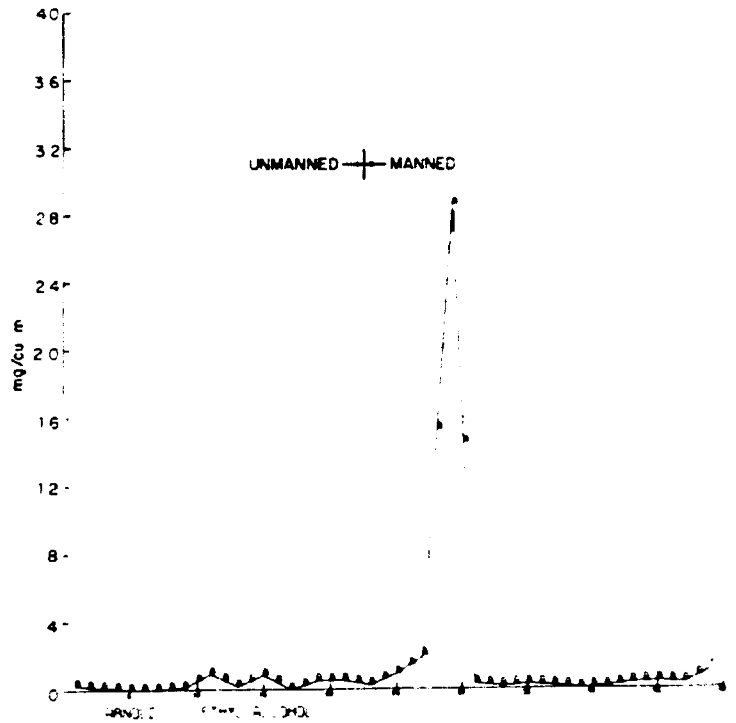
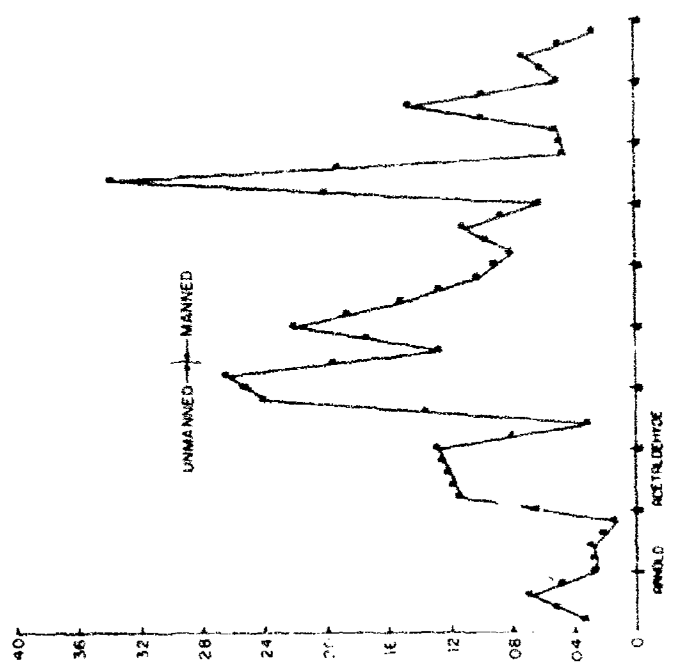
mg/cu m


mg/cu m
40
36
32
28
24
20
16
12
06
04
0
UNMANNED MANNED
METHYL ALCOHOL


mg/cu m
40
36
32
28
24
20
16
12
8
4
0
UNMANNED MANNED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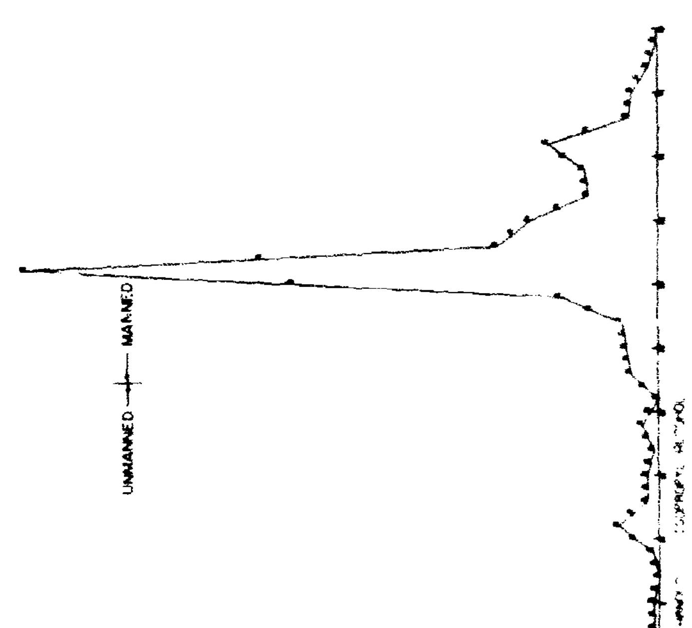
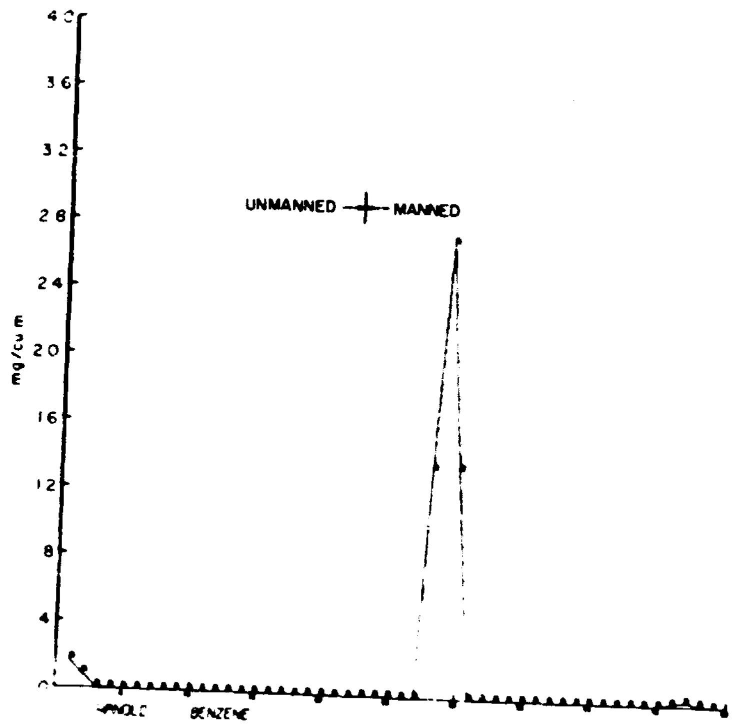
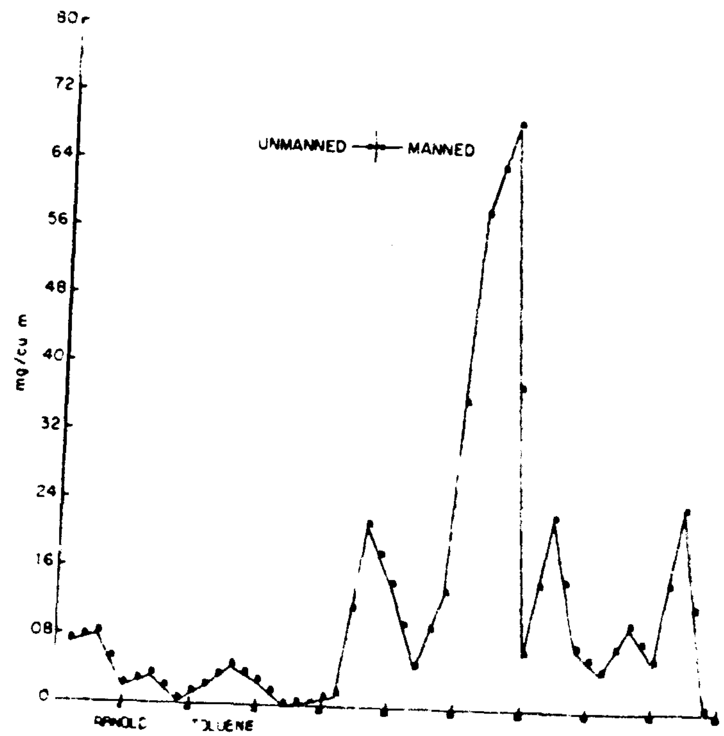
MANNED
mg/cu m
ACETALDEHYDE

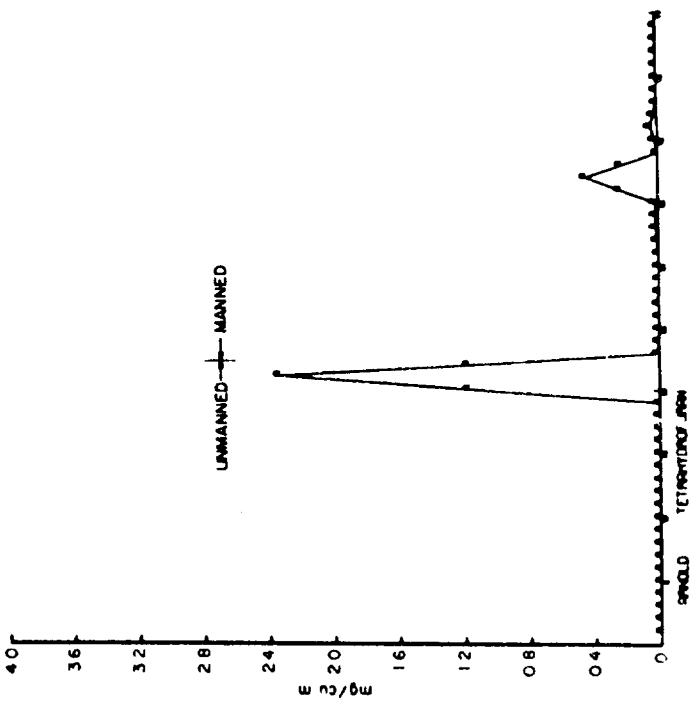

UNMANNED
MANNED
mg/cu m



4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
.8
.4
0
mg/cu m
UNMANNED MANNED
BENZENE



80
72
64
56
48
40
32
24
16
08
0
mg/cu m
UNMANNED MANNED
TOLUENE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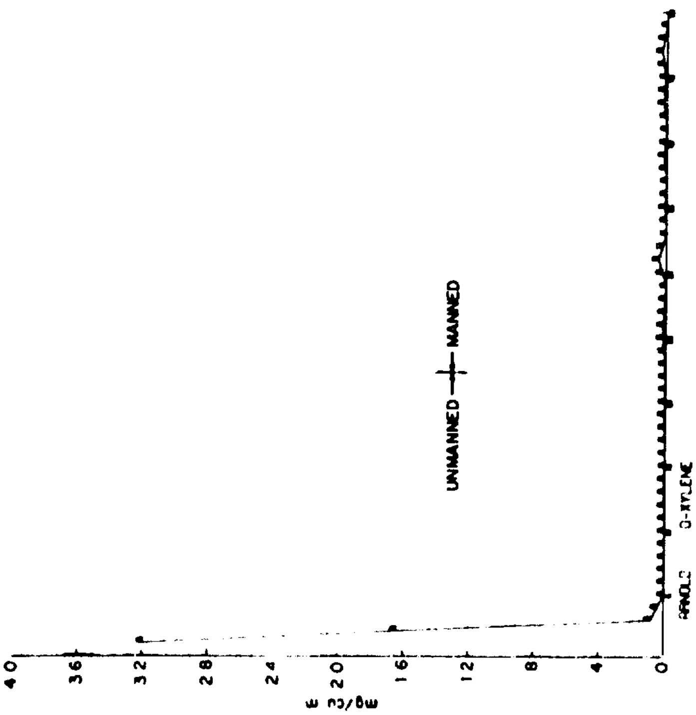
MANNED
mg/cu m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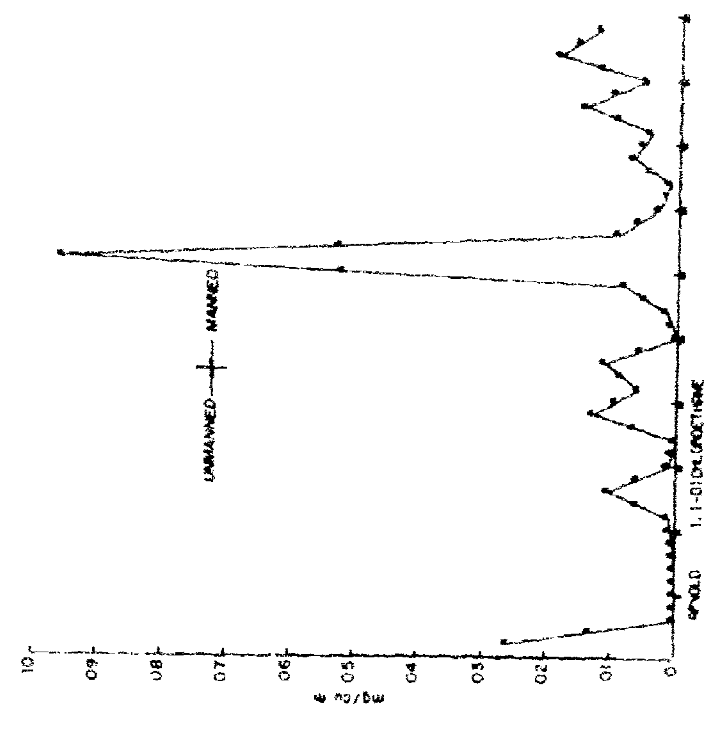
MANNED
O-XYLENE
mg/cu m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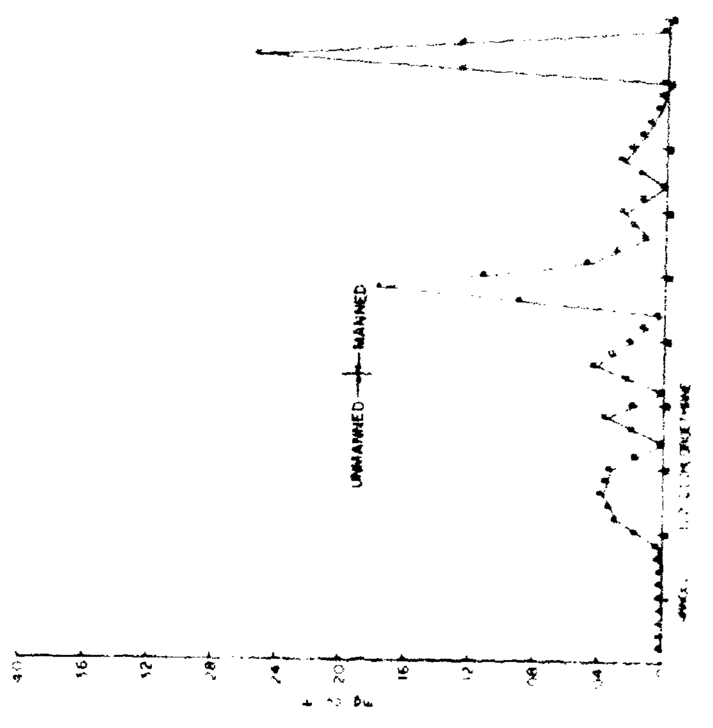
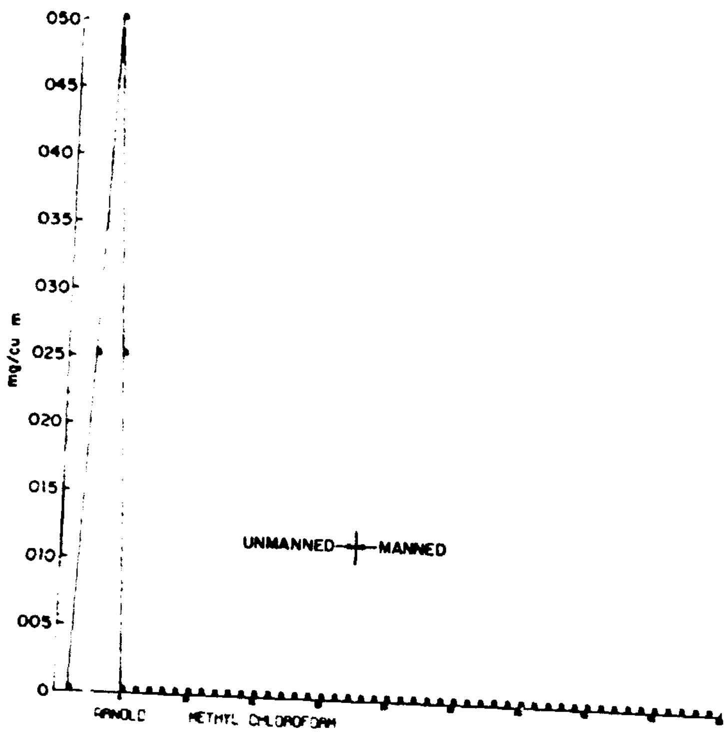
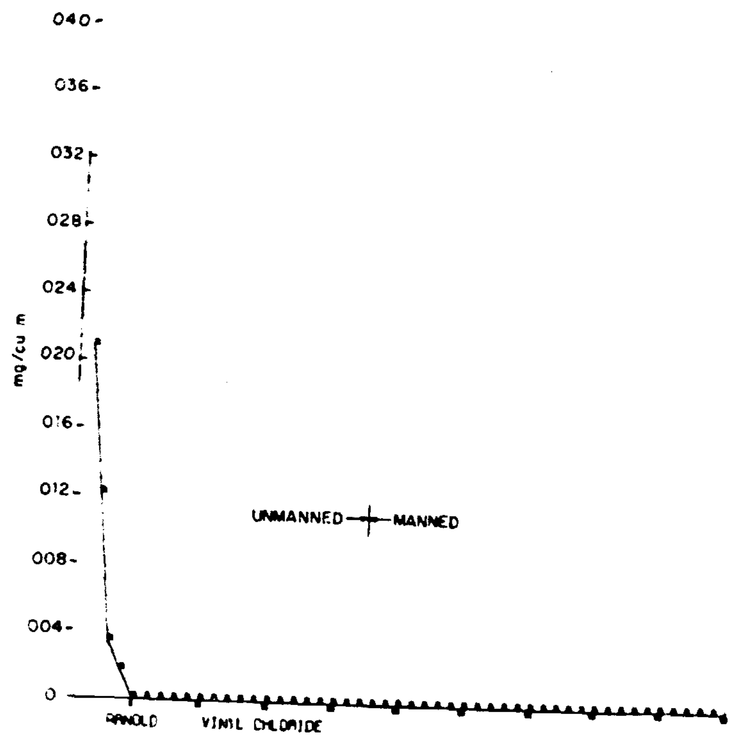
MANNED
APOLLO
1,1-DICHLOROETHANE
mg/cu m

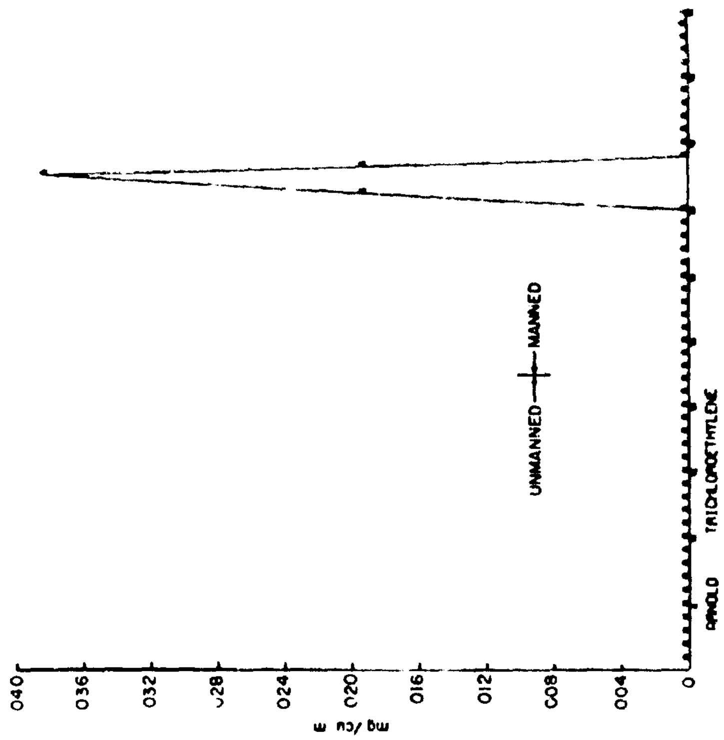

UNMANNED
MANNED



mg/cu m
050
045
040
035
030
025
020
015
010
005
0
ARNOLD
METHYL CHLOROFORM
UNMANNED
MANNED



mg/cu m
040
036
032
028
024
020
016
012
008
004
0
ARNOLD
VINIL CHLORIDE
UNMANNED
MANNED


mg/cu m
.040
.036
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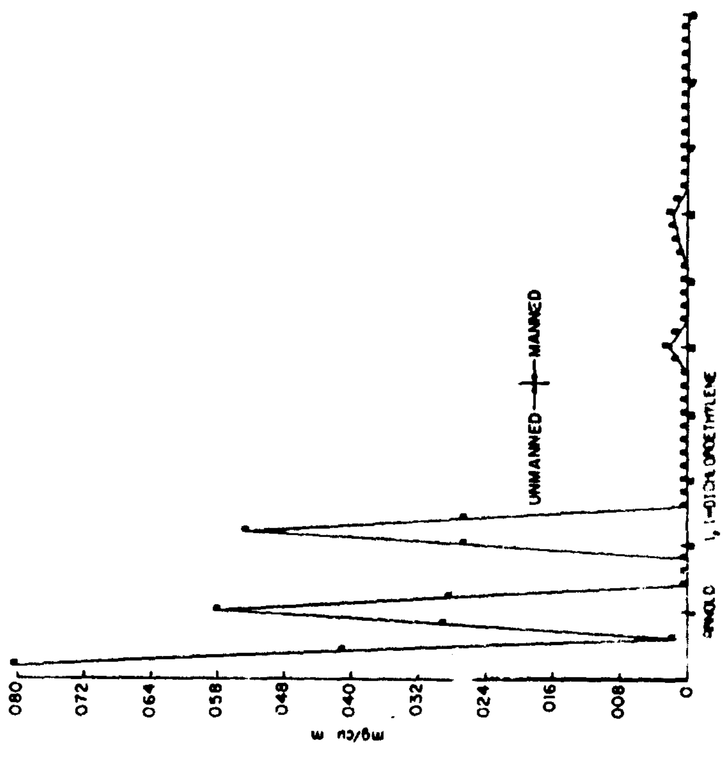
.024
.020
.016
.012
.008
.004
0
UNMANNED — MANNED
TRICHLOROETHYLENE


mg/cu m
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.008
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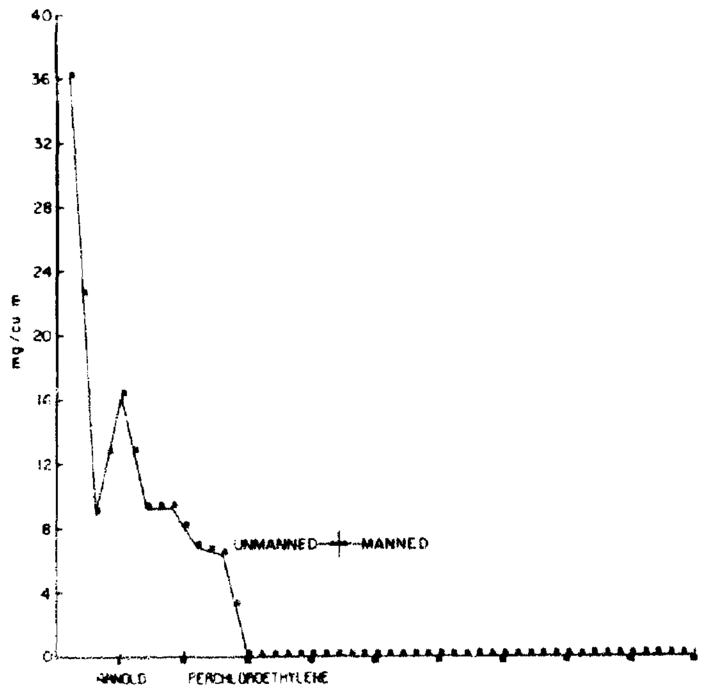
UNMANNED — MANNED
1, 1-DICHLOROETHYLENE



mg/cu m
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36
32
28
24
20
16
12
8
4
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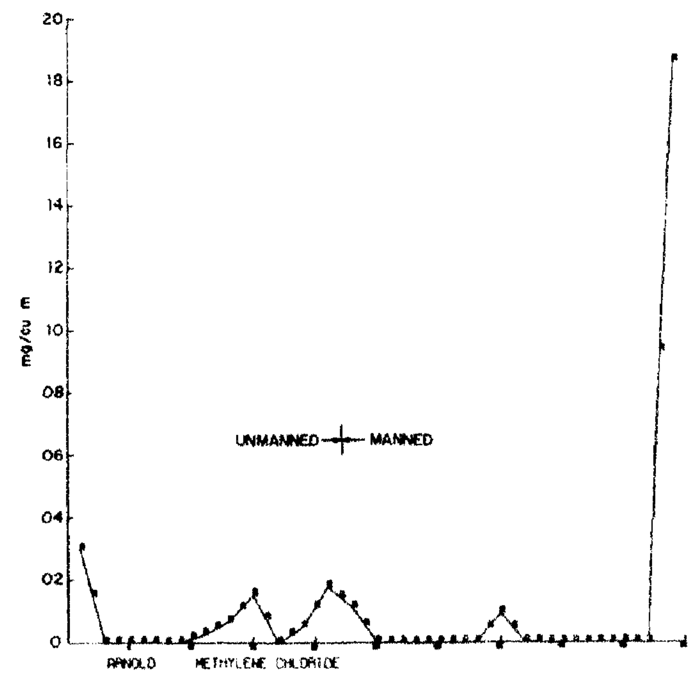
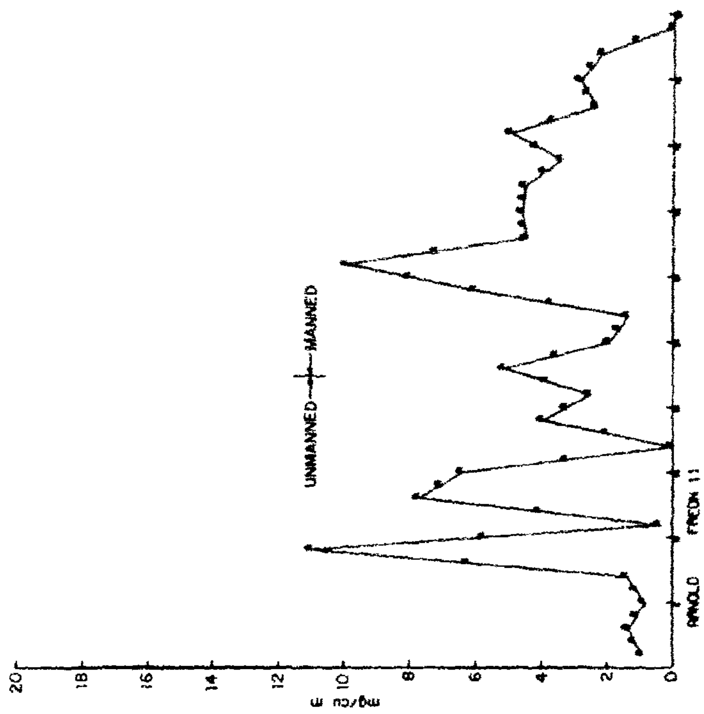
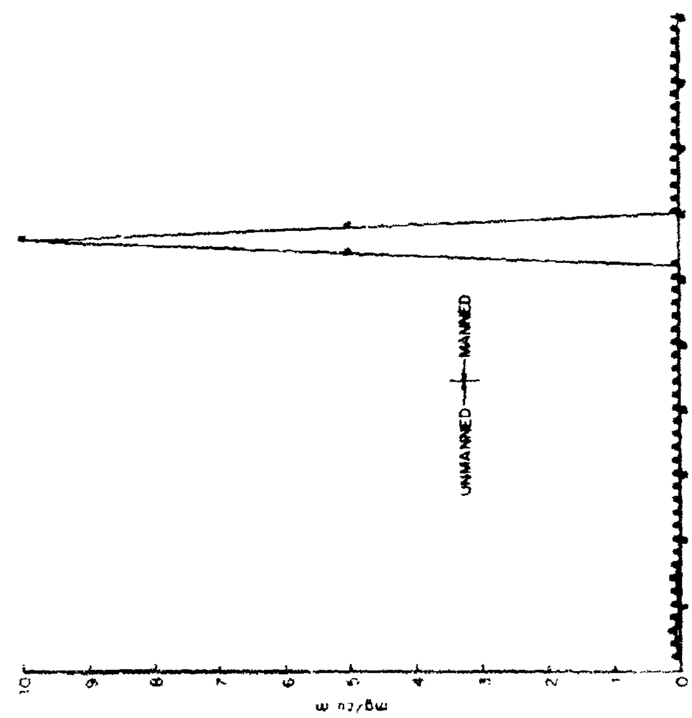
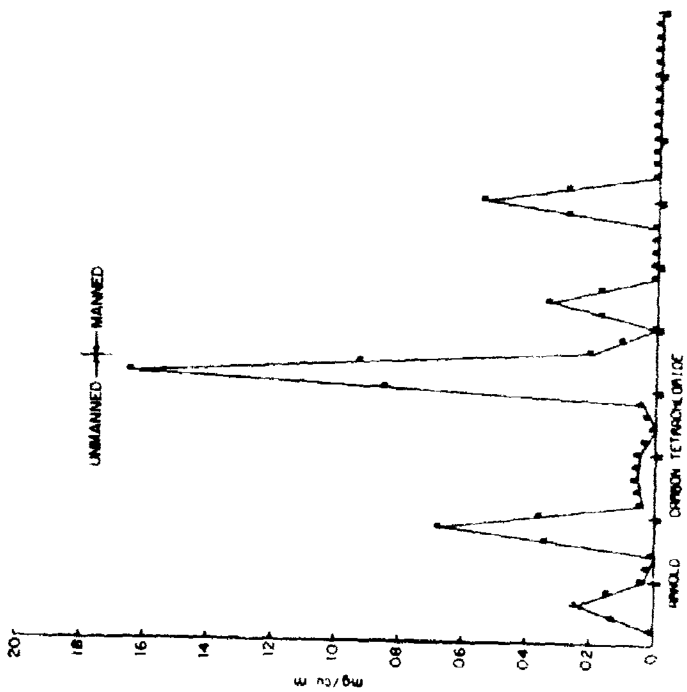
ARNOLD PERCHLOROETHYLENE



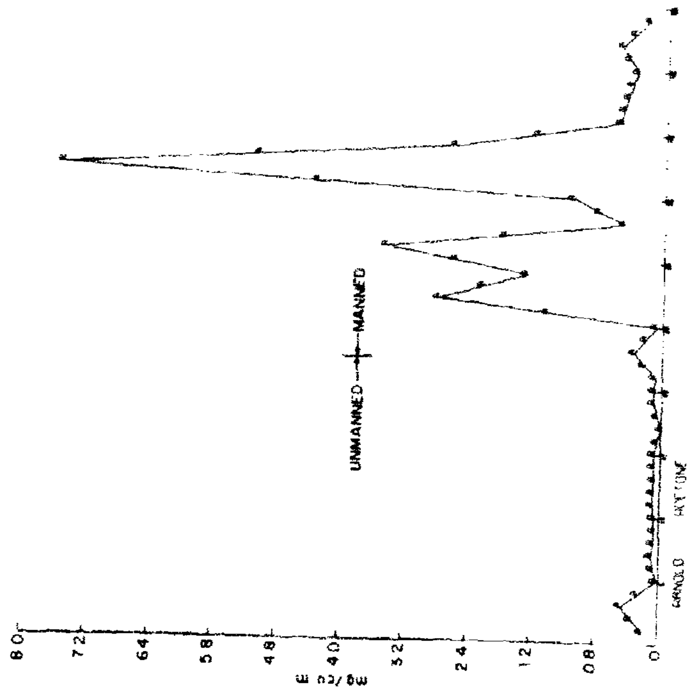
mg/cu m
20
18
16
14
12
10
08
06
04
02
0
UNMANNED MANNED
ARNOLD METHYLENE CHLORIDE


UNMANNED —+— MANNED
mg/cu m
20
18
16
14
12
10
8
6
4
2
0
ARNOLD
FREON 11


UNMANNED —+— MANNED
mg/cu m
10
9
8
7
6
5
4
3
2
1
0
ARNOLD
CHLOROFORM



UNMANNED
MANNED
mg/cu m
MANIFOLD
CARBON TETRACHLORIDE



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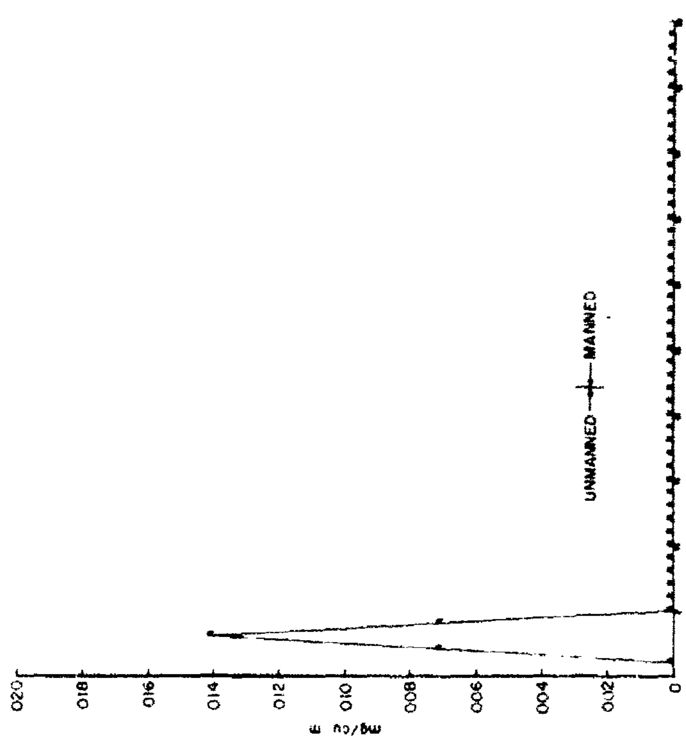
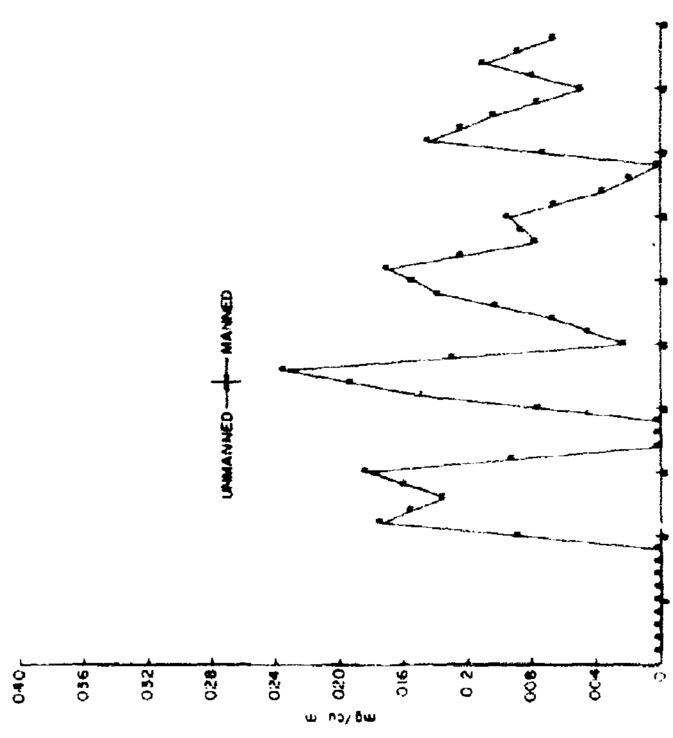
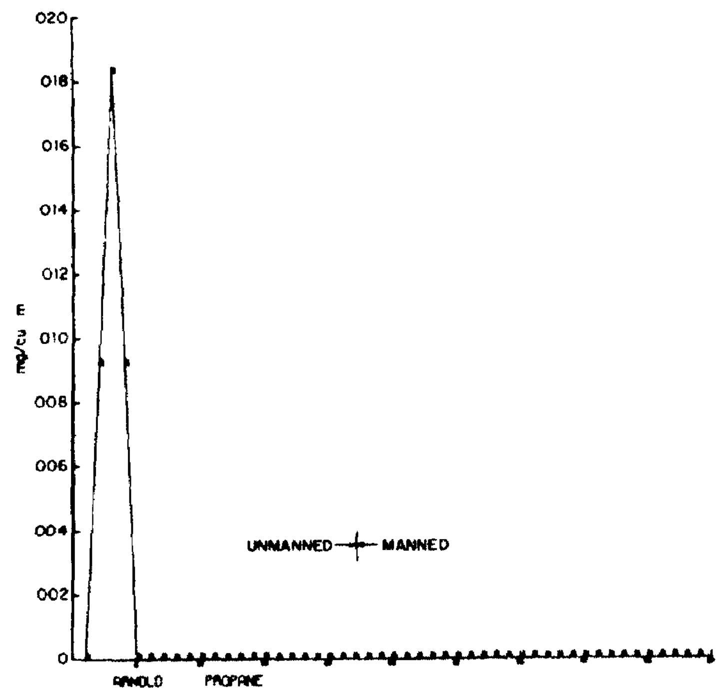
MANNED
mg/cu m
MANIFOLD
ACETONE



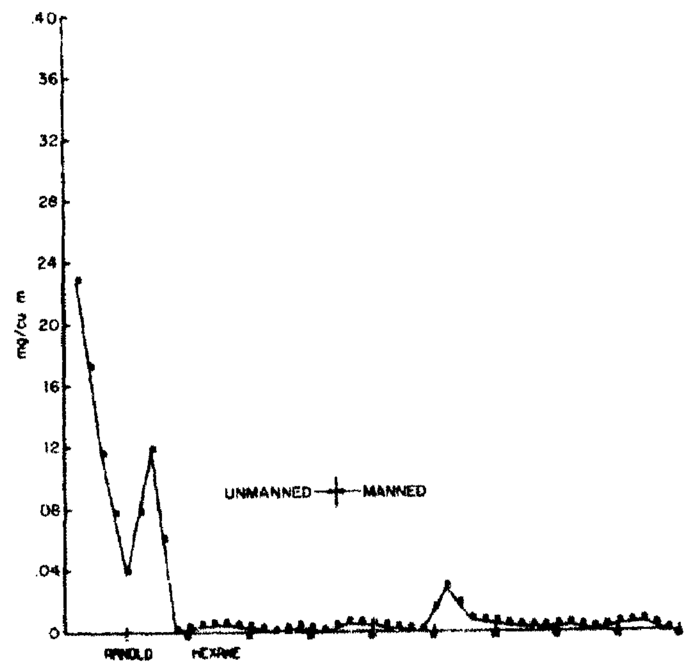
UNMANNED
MANNED
RANOLD
ETHANE
mg/cu m



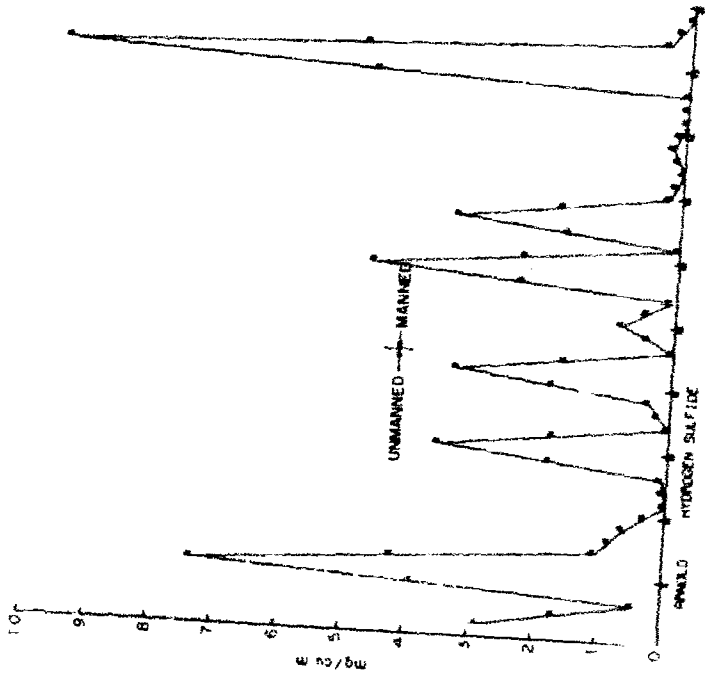
UNMANNED
MANNED
RANOLD
METHYL ETHYL KETONE
mg/cu m

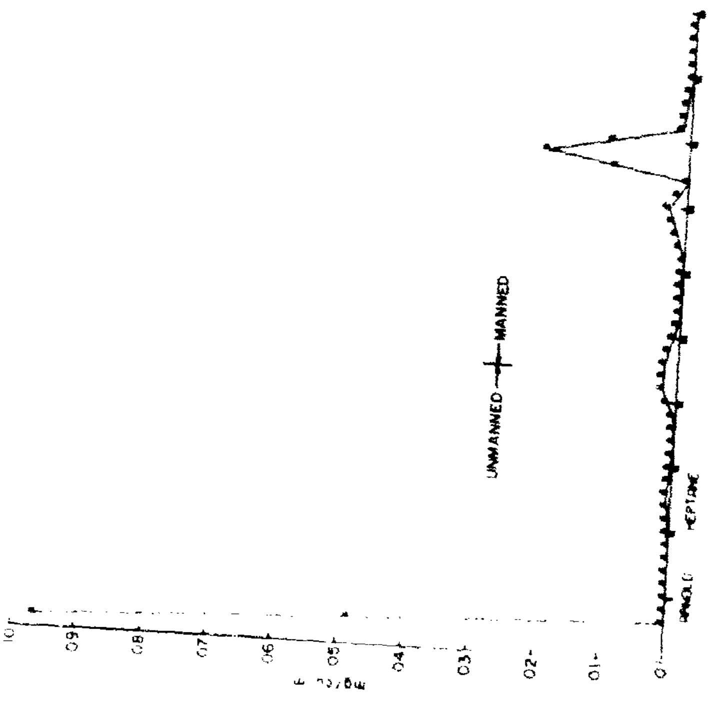


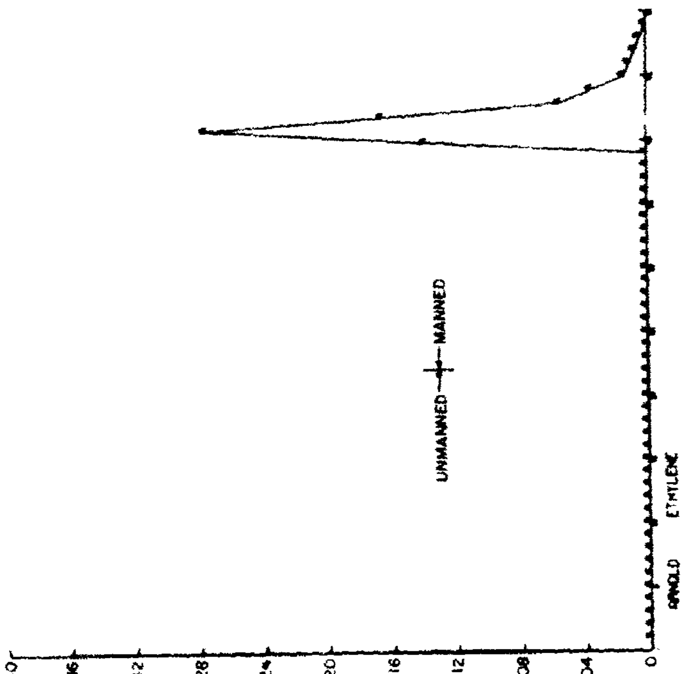
.020
.018
.016
.014
.012
.010
.008
.006
.004
.002
0
mg/cu m
UNMANNED MANNED
RANOLO
PROPANE



.40
.36
.32
.28
.24
.20
.16
.12
.08
.04
0
mg/cu m
UNMANNED MANNED
RANOLO
HEXANE


mg/cu m
UNMANNED
MANNED
HYDROGEN SULFIDE

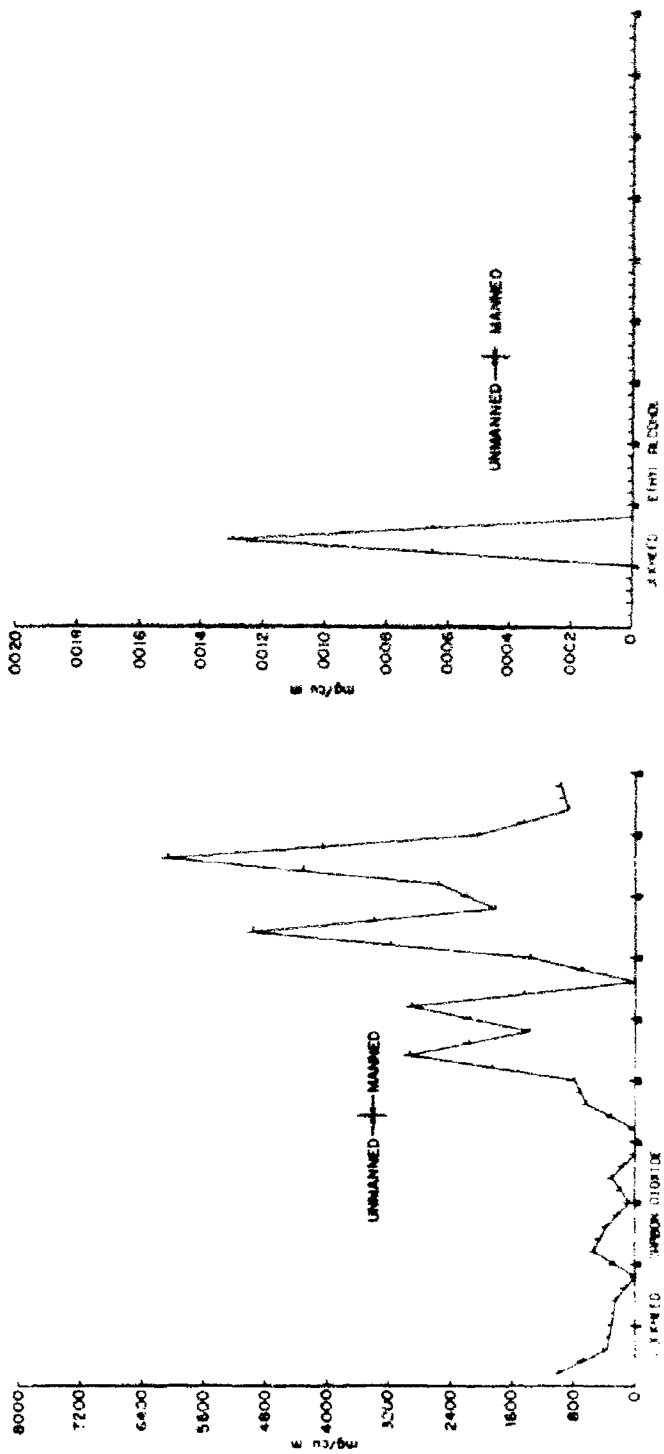

mg/cu m
UNMANNED
MANNED
HEPTANE


UNMANNED MANNED
mg/cu m
040
036
032
028
024
020
016
012
008
004
0
ARNOLD
ETHYLENE

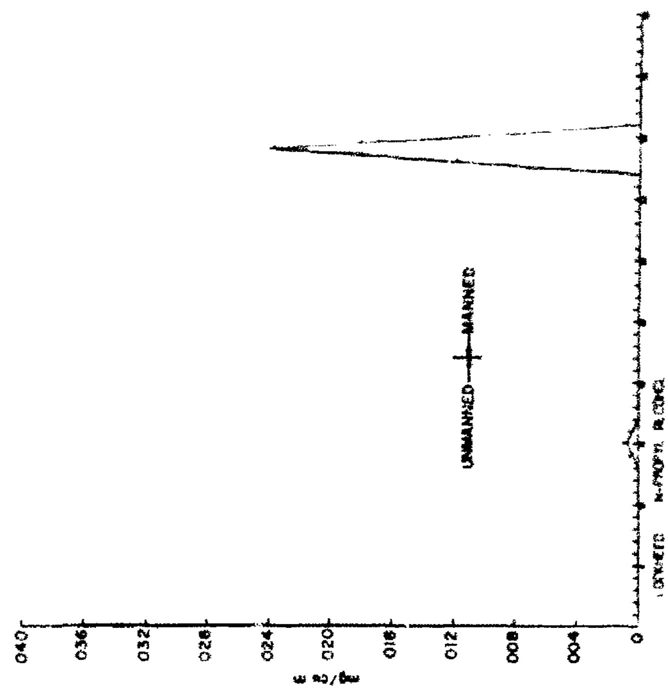
APPENDIX II

A DETAILED STUDY OF CONTAMINANT PRODUCTION IN A SPACE CABIN SIMULATOR AT 760 MM. HG

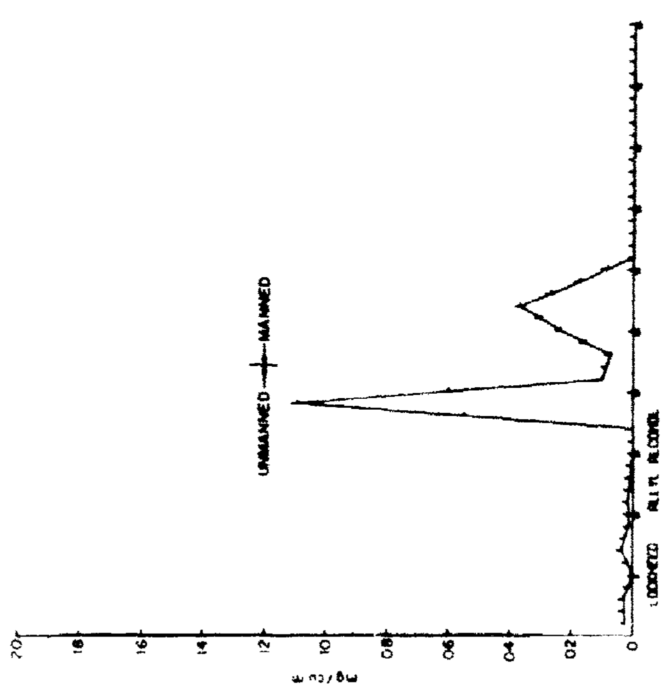
Graphic Representation of Compounds
(Lockheed Missiles and Space Company)



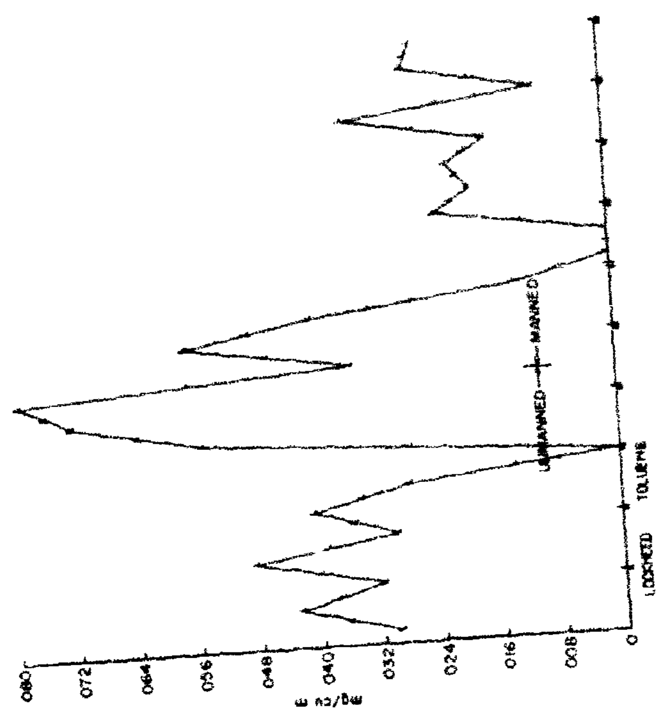
UNMANNED — MANNED
CARBON DIOXIDE
mg/cu m
UNMANNED — MANNED
ETHYL ALCOHOL
mg/cu m

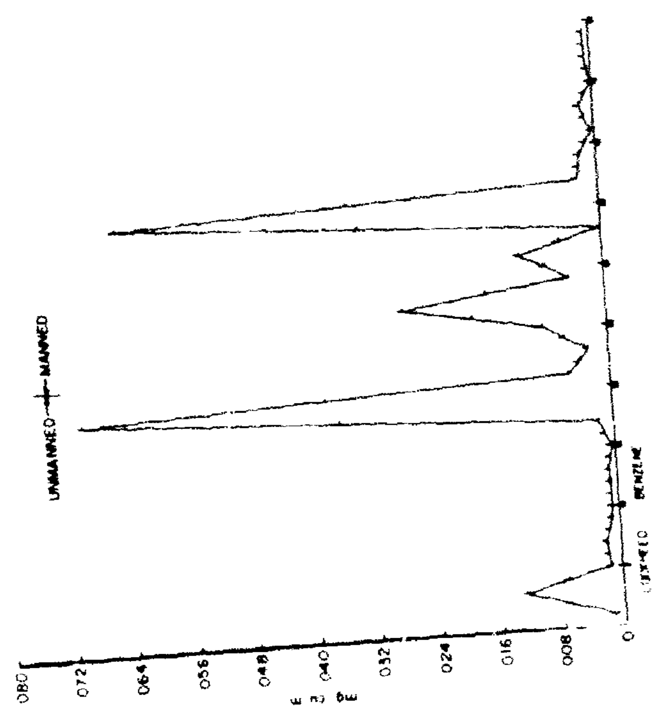


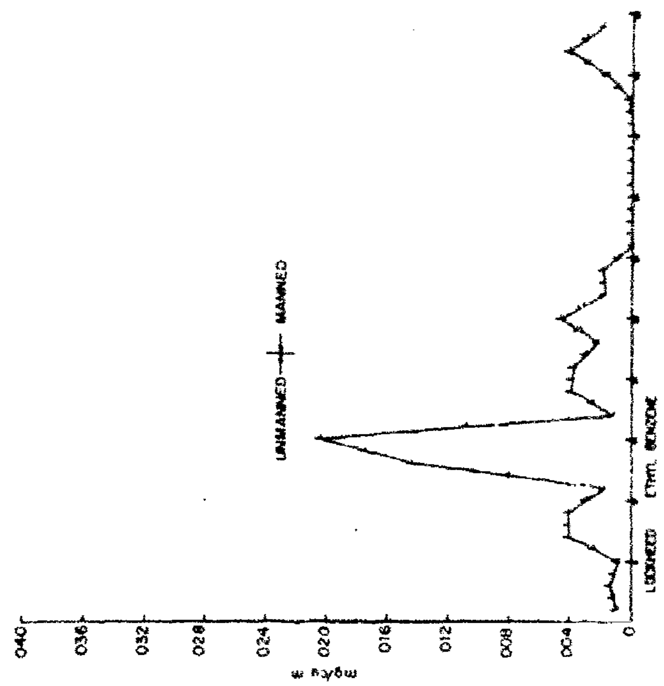
UNMANNED
MANNED
LOCKHEED
N-PROPYL ALCOHOL
mg/cu m



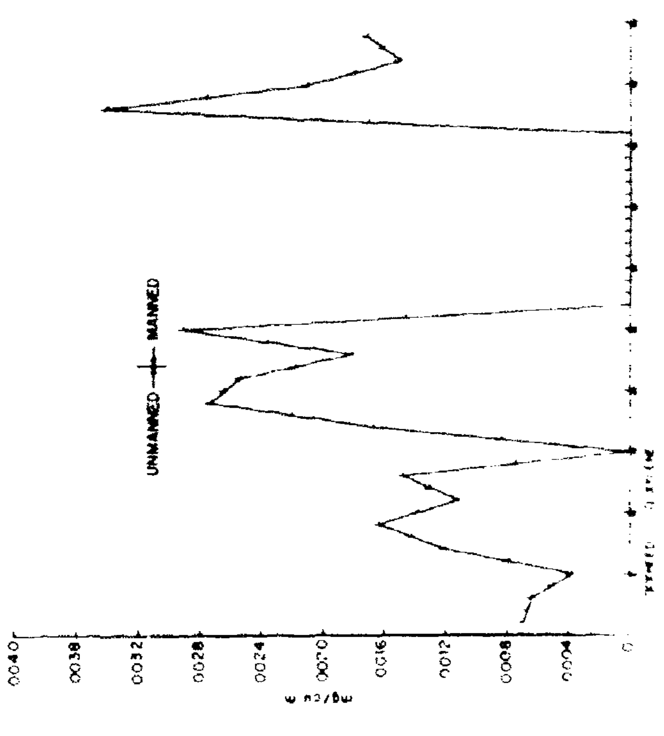
UNMANNED
MANNED
LOCKHEED
ALLYL ALCOHOL
mg/cu m


mg/cu m
080
072
064
056
048
040
032
024
016
008
0
UNMANNED
MANNED
LOCKHEED
TOLUENE

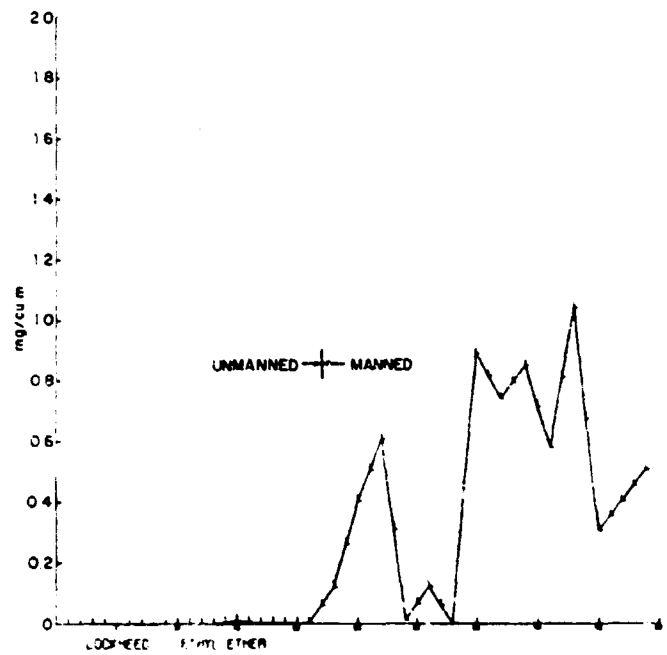

mg/cu m
080
072
064
056
048
040
032
024
016
008
0
UNMANNED
MANNED
BENZENE

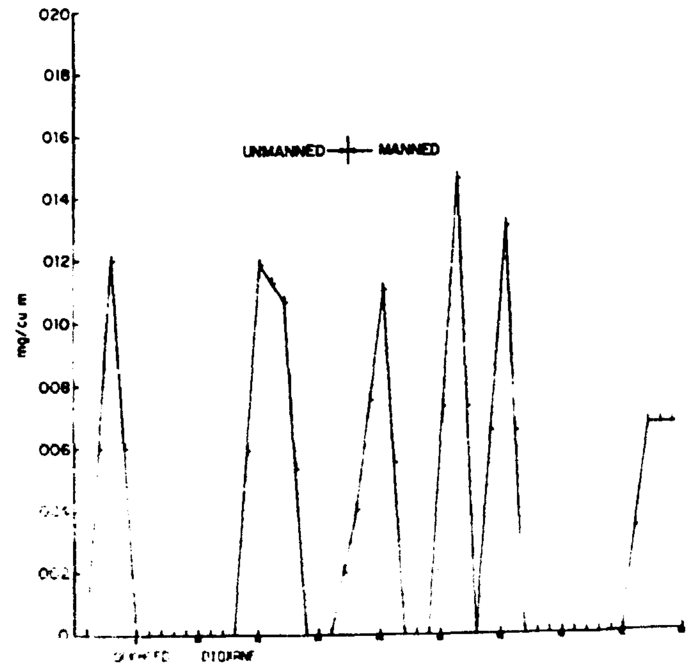


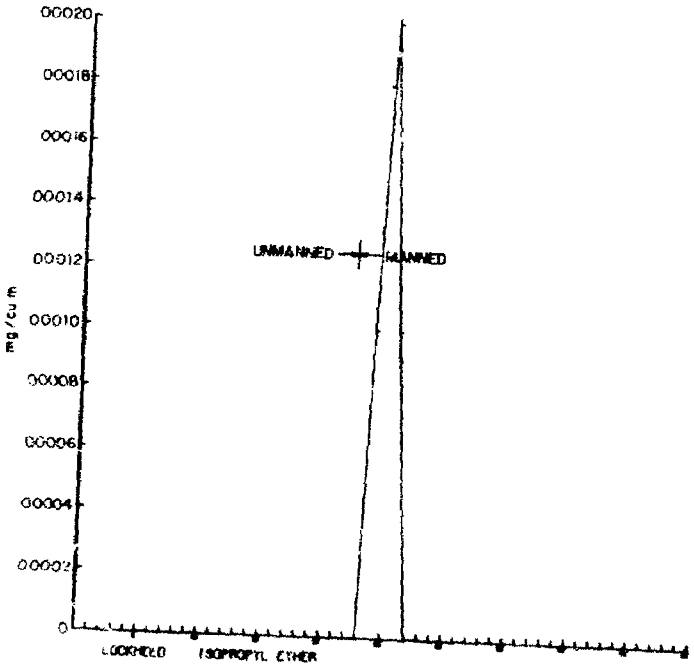
UNMANNED
MANNED
ETHYL BENZENE
mg/cu m

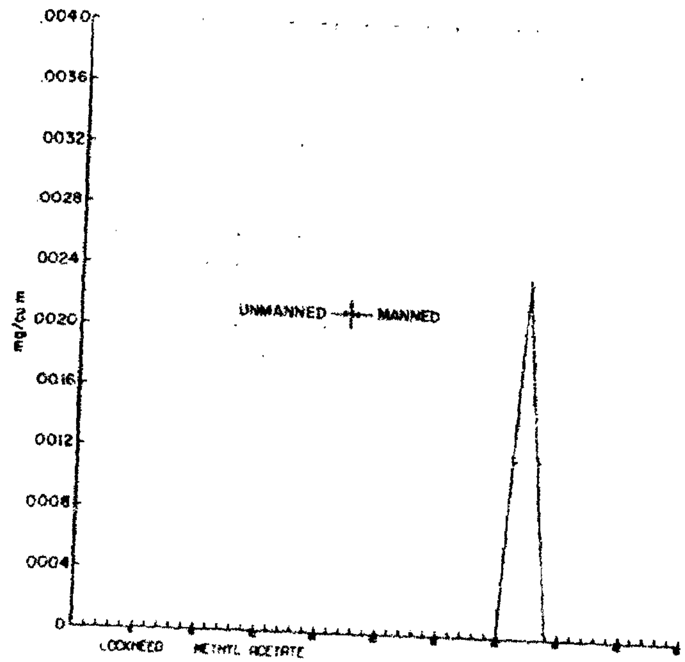


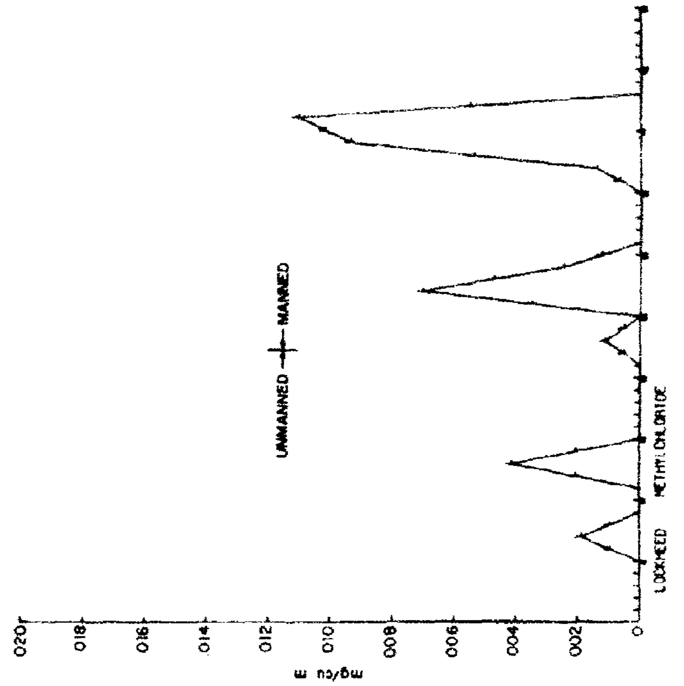
UNMANNED
MANNED
mg/cu m


2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
mg/cu m
UNMANNED
MANNED
ETHER

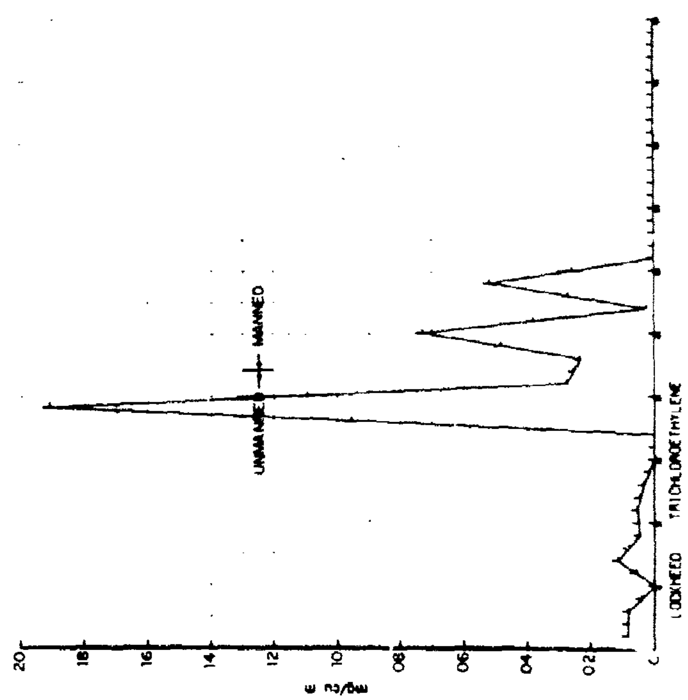

020
018
016
014
012
010
008
006
0
mg/cu m
UNMANNED
MANNED


.00020
.00018
.00016
.00014
.00012
.00010
.00008
.00006
.00004
.00002
0
mg/cu m
UNMANNED
MANNED
LOCKHEED
ISOPROPYL ETHER

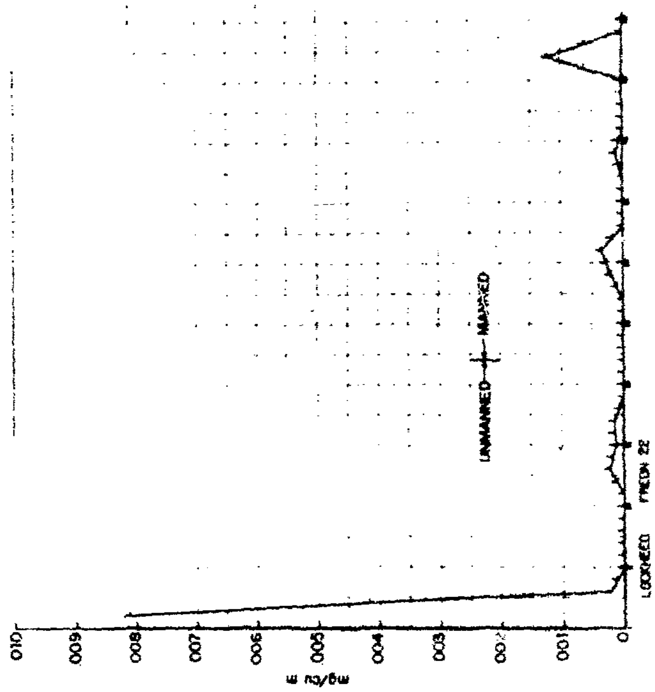

.0040
.0036
.0032
.0028
.0024
.0020
.0016
.0012
.0008
.0004
0
mg/cu m
UNMANNED
MANNED
LOCKHEED
METHYL ACETATE

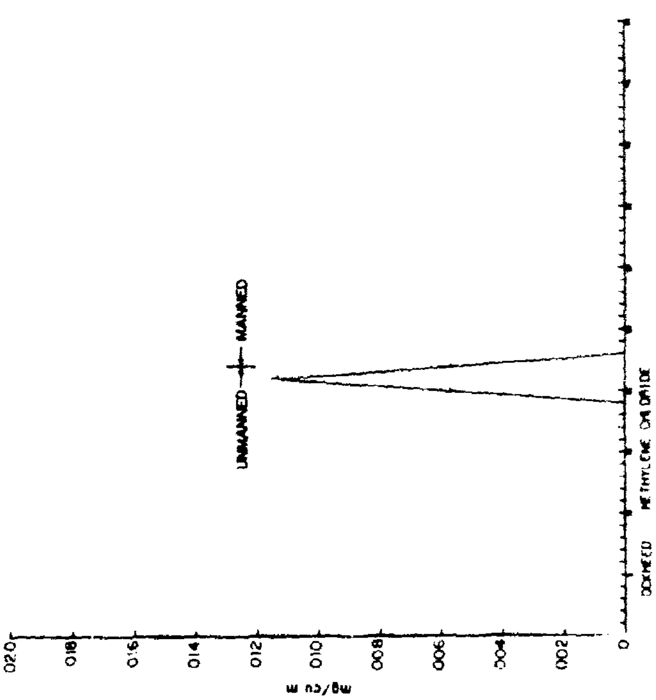


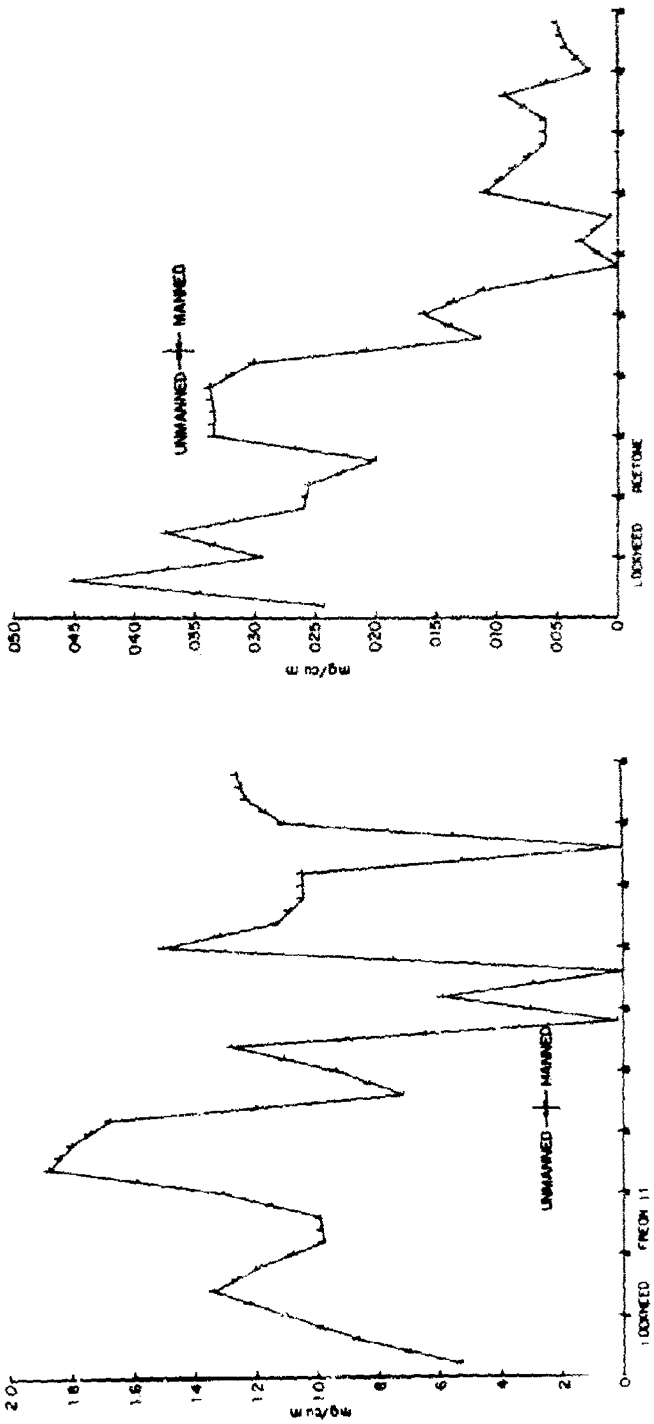
mg/cu m
0
002
004
006
008
010
012
014
016
018
020
LOCKHEED METHYL CHLORIDE
UNMANNED MANNED



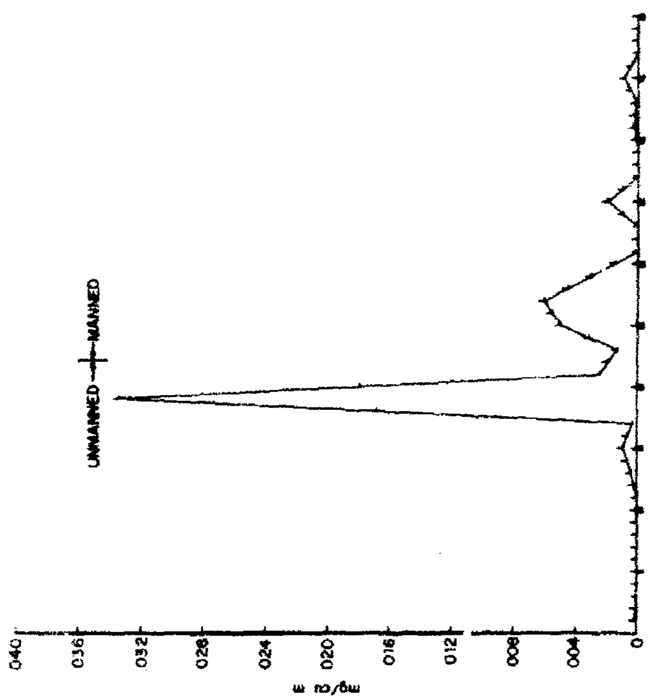
mg/cu m
0
02
04
06
08
10
12
14
16
18
20
LOCKHEED TRICHLOROETHYLENE
UNMANNED MANNED

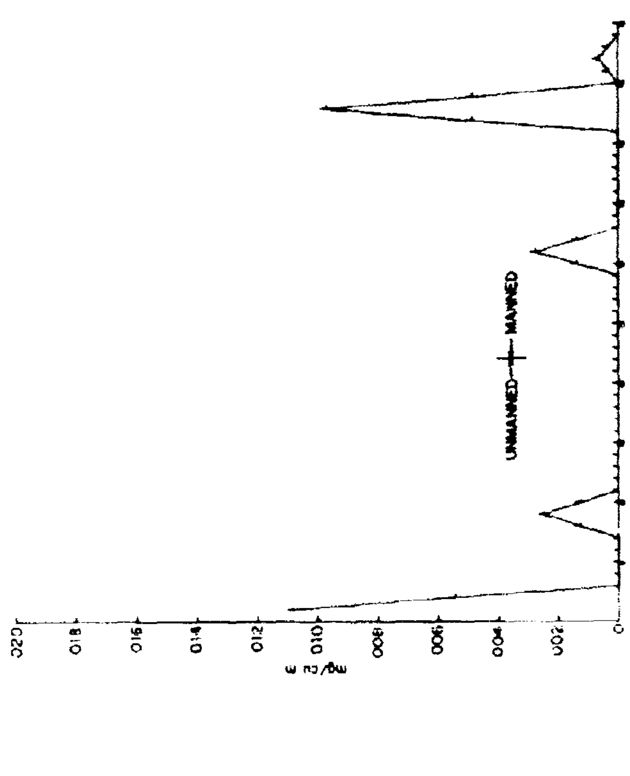

mg/cu m
010
009
008
007
006
005
004
003
002
001
0
UNMANNED
MANNED
LOCKHEED
FREON 22

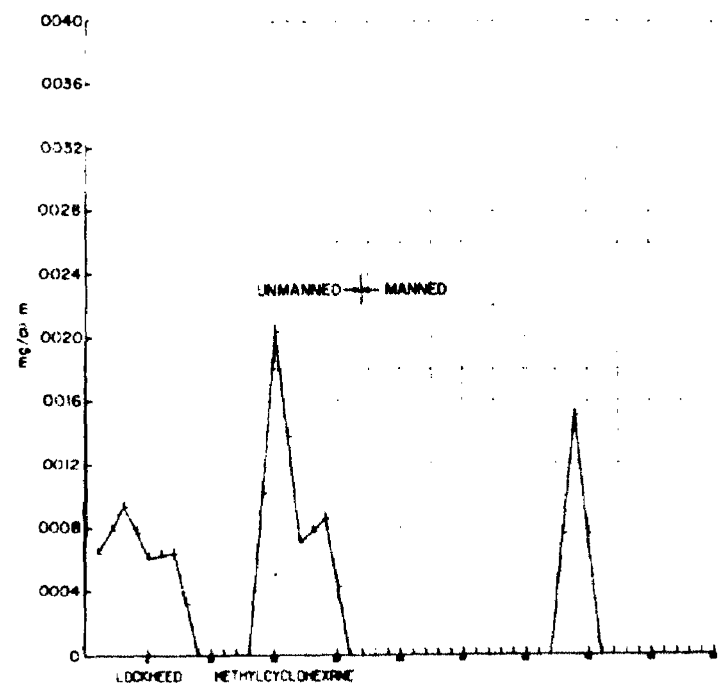

mg/cu m
020
018
016
014
012
010
008
006
004
002
0
UNMANNED
MANNED
LOCKHEED
METHYLENE CHLORIDE



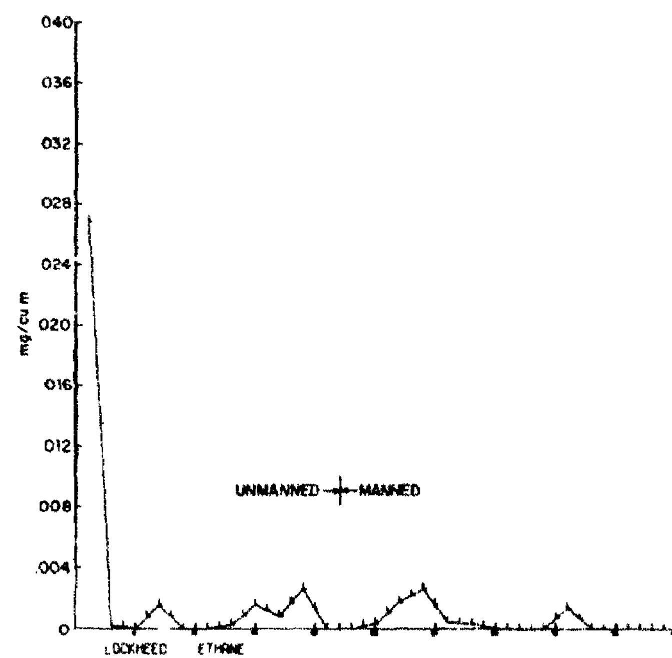
UNMANNED — MANNED
mg/cu m
LOCKHEED
ACETONE
UNMANNED — MANNED
mg/cu m
LOCKHEED
FREON 11


UNMANNED MANNED
LOCKHEED CYCLOHEXANE
mg/cu m
040
036
032
028
024
020
016
012
008
004
0

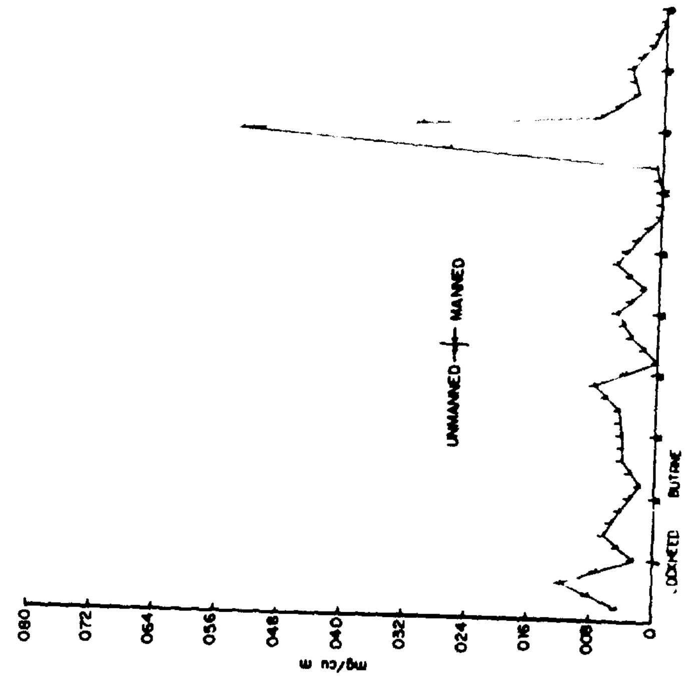

UNMANNED MANNED
LOCKHEED CYCLOPROPANE
mg/cu m
020
018
016
014
012
010
008
006
004
002
0



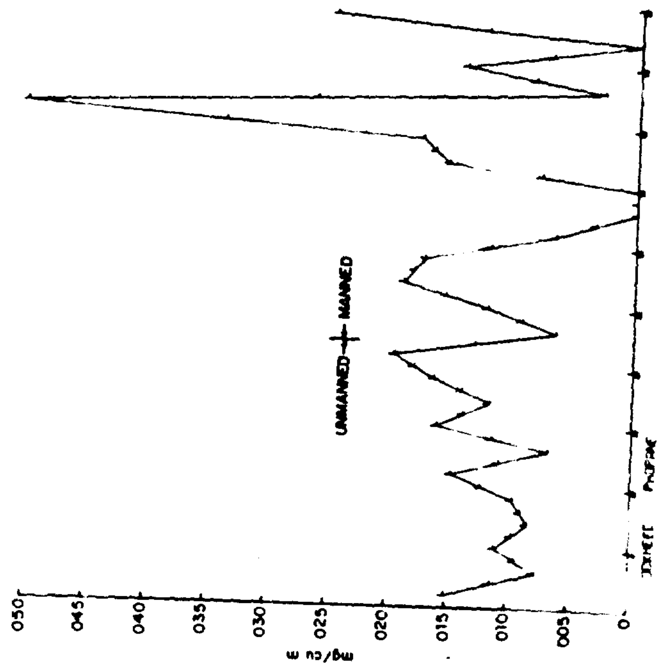
0040
0036
0032
0028
0024
0020
0016
0012
0008
0004
0
mg/cu m
UNMANNED MANNED
LOCKHEED METHYLCYCLOHEXANE



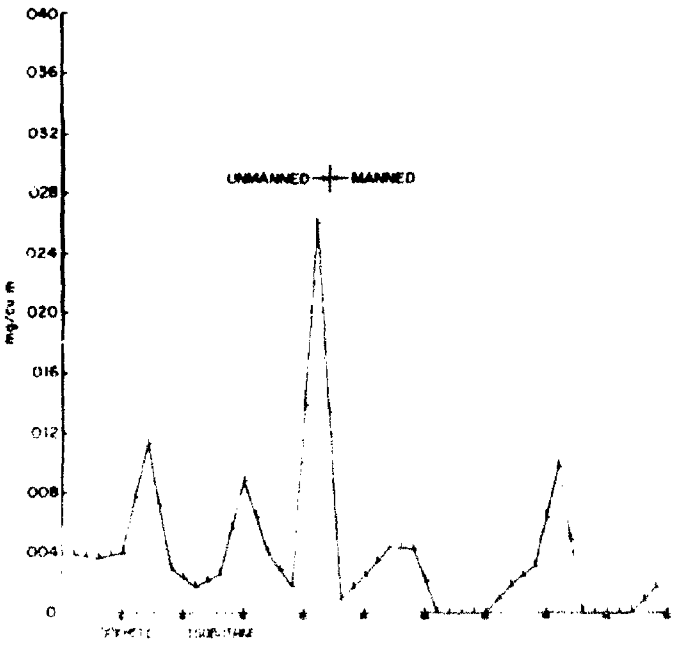
040
036
032
028
024
020
016
012
008
.004
0
mg/cu m
UNMANNED MANNED
LOCKHEED ETHANE



mg/cu m
080
072
064
056
048
040
032
024
016
008
0
UNMANNED MANNED
BUTANE



mg/cu m
050
045
040
035
030
025
020
015
010
005
0
UNMANNED MANNED
PROPANE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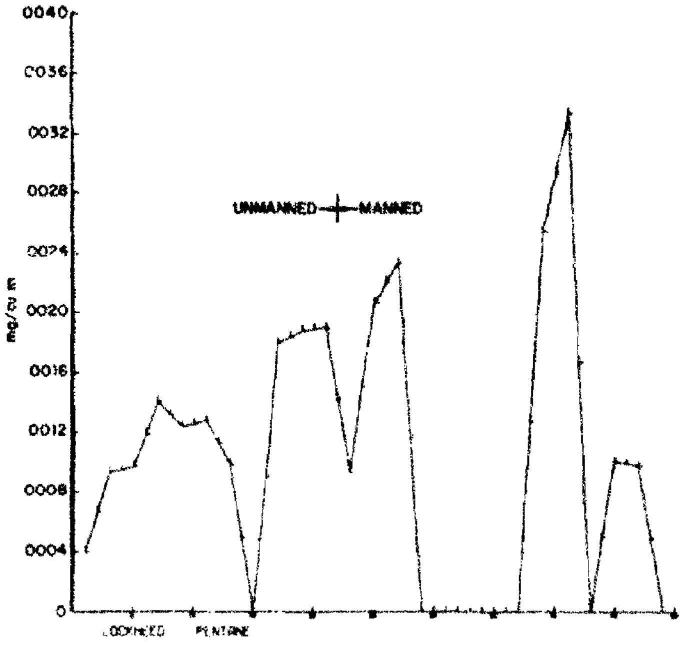
036
032
028
024
020
016
012
008
004
0
mg/cu m
UNMANNED
MANNED


0040
0036
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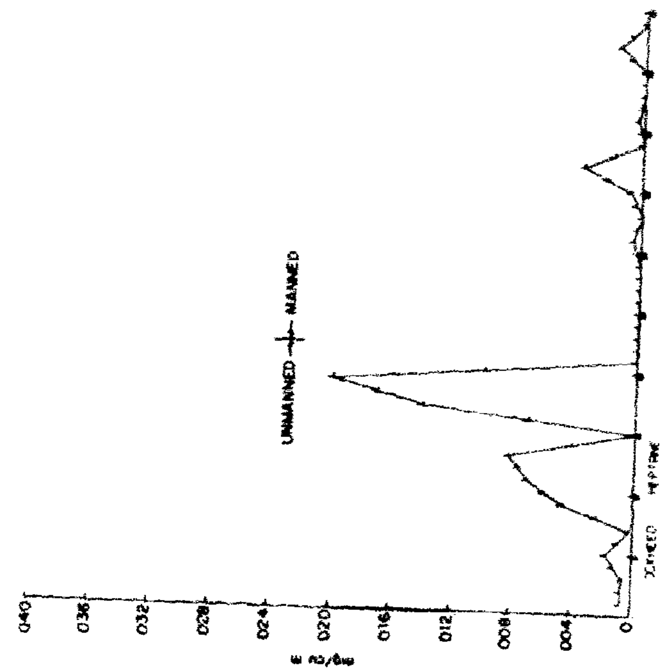
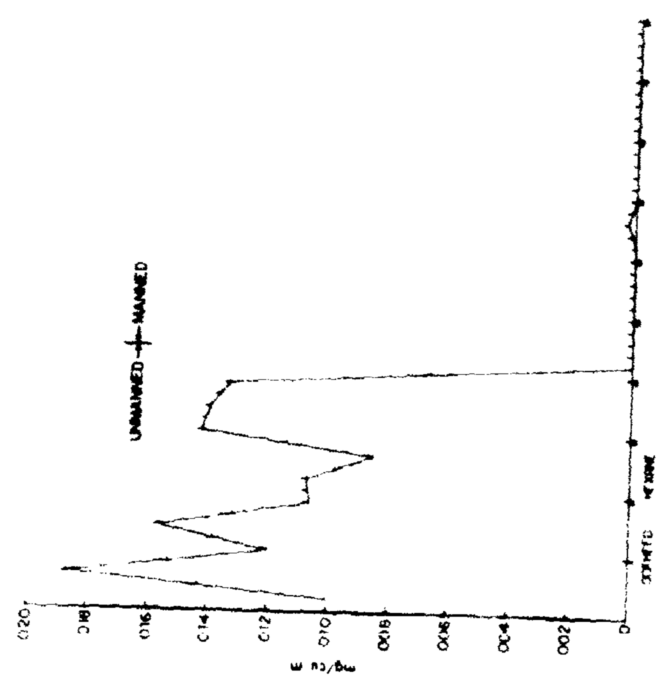
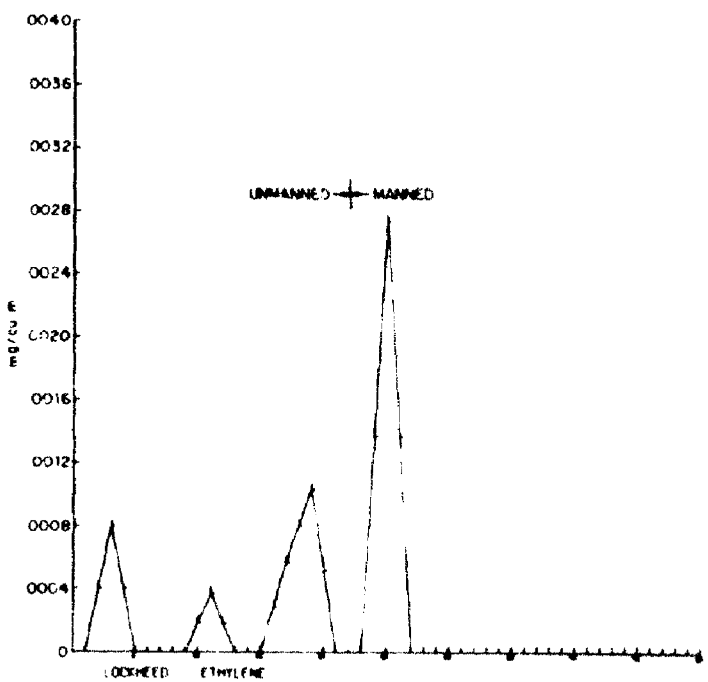
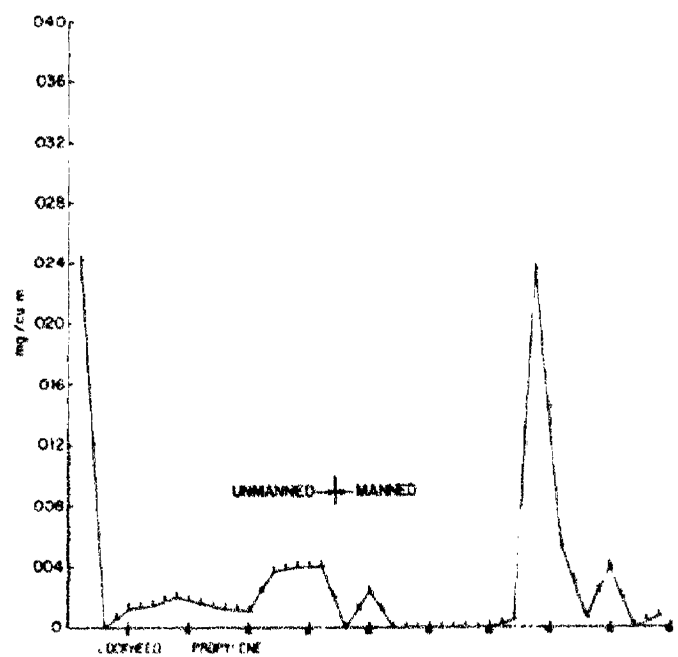
0028
0024
0020
0016
0012
0008
0004
0
mg/cu m
UNMANNED
MANNED
LOCKHEED
PENTANE


UNMANNED
MANNED
mg/cu m
040
036
032
028
024
020
016
012
008
004
0


UNMANNED
MANNED
mg/cu m
020
018
016
014
012
010
008
006
004
002
0



0040
0036
0032
0028
0024
0020
0016
0012
0008
0004
0
mg/cu m
UNMANNED MANNED
LOCKHEED ETHYLENE



040
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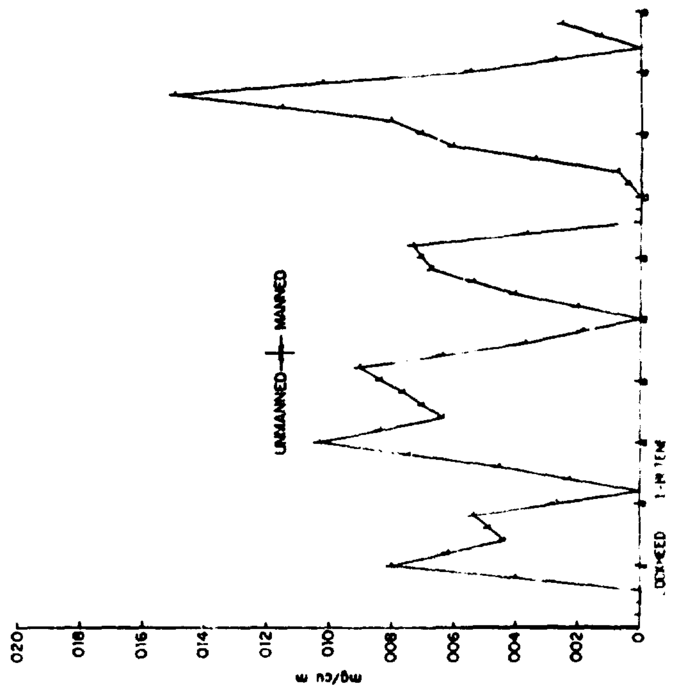
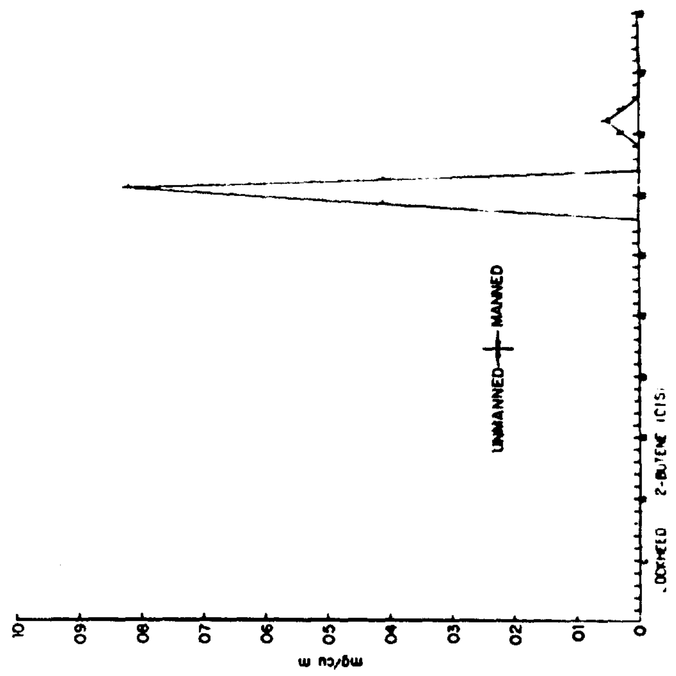
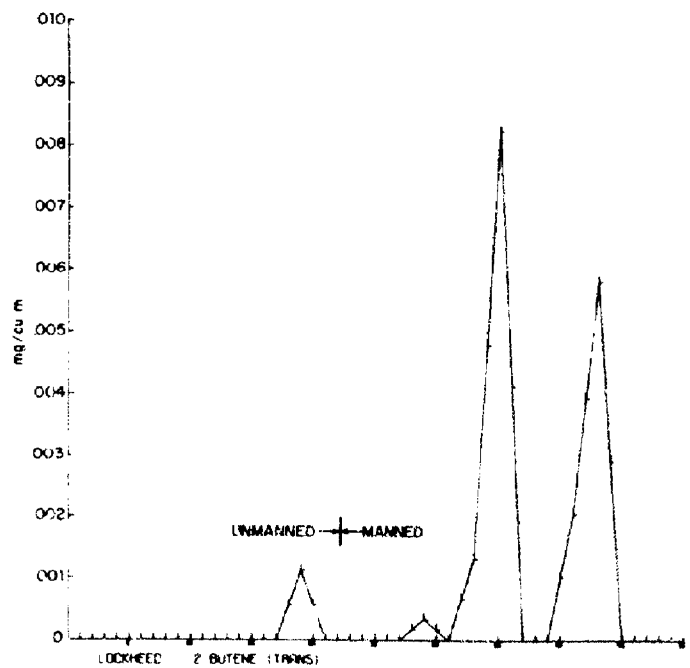
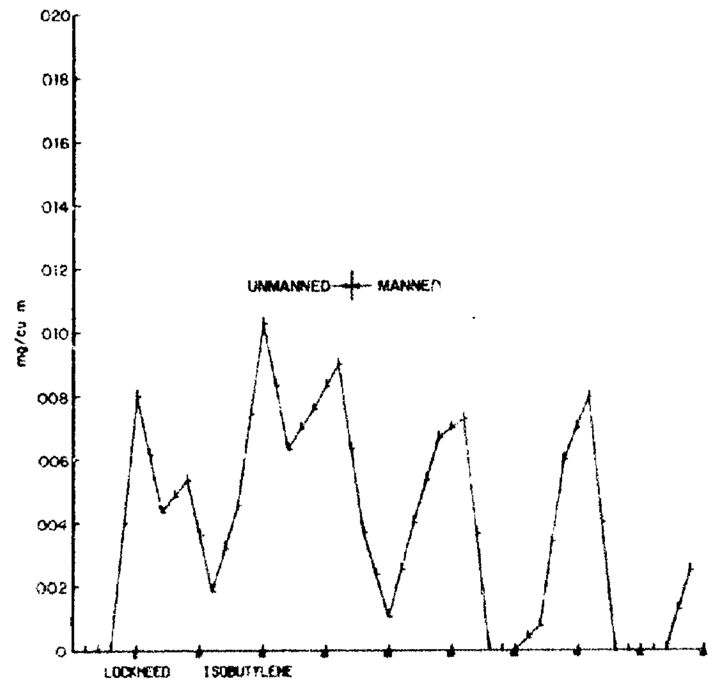
032
028
024
020
016
012
008
004
0
mg/cu m
UNMANNED MANNED
LOCKHEED PROPYLENE


mg/cu m
020
018
016
014
012
010
008
006
004
002
0
UNMANNED
MANNED
LOCKHEED

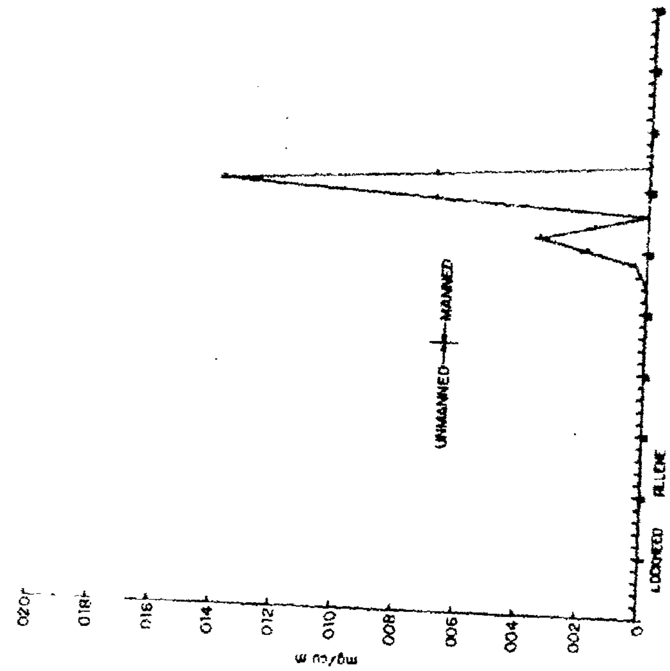

mg/cu m
10
09
08
07
06
05
04
03
02
01
0
UNMANNED
MANNED
LOCKHEED
2-BUTENE (CIS)

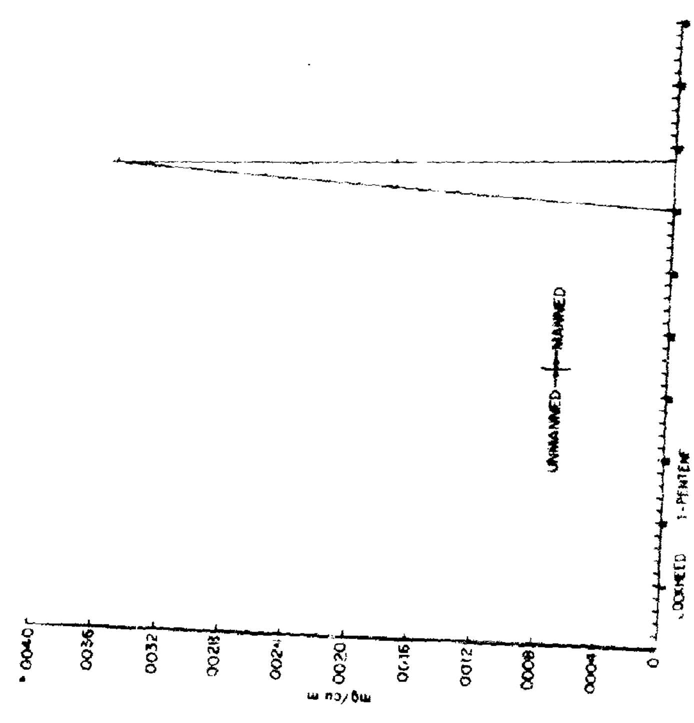


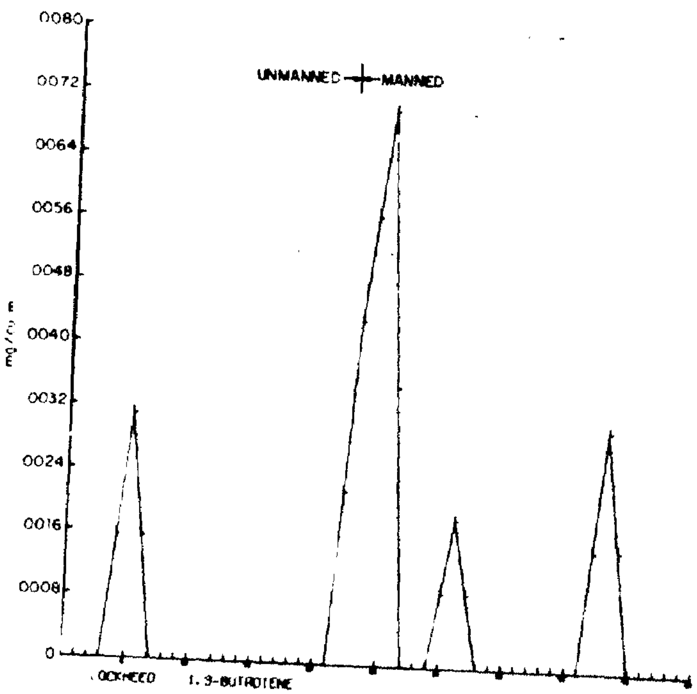
.010
.009
.008
.007
.006
.005
.004
.003
.002
.001
0
mg/cu m
UNMANNED
MANNED
LOCKHEED 2 BUTENE (TRANS)

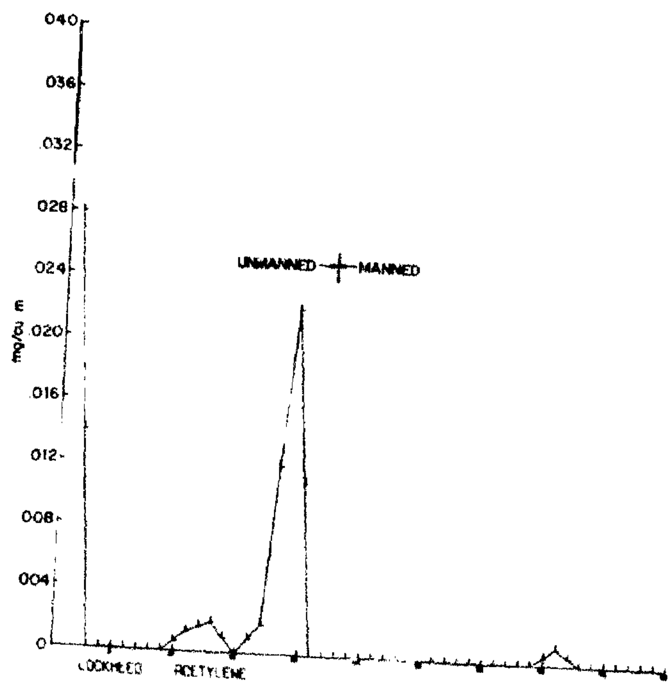


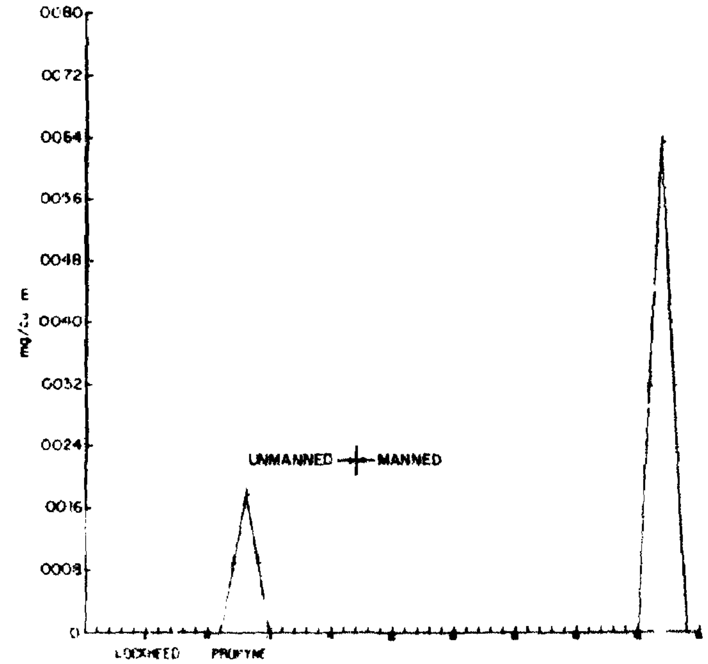
.020
.018
.016
.014
.012
.010
.008
.006
.004
.002
0
mg/cu m
UNMANNED
MANNED
LOCKHEED ISOBUTYLENE

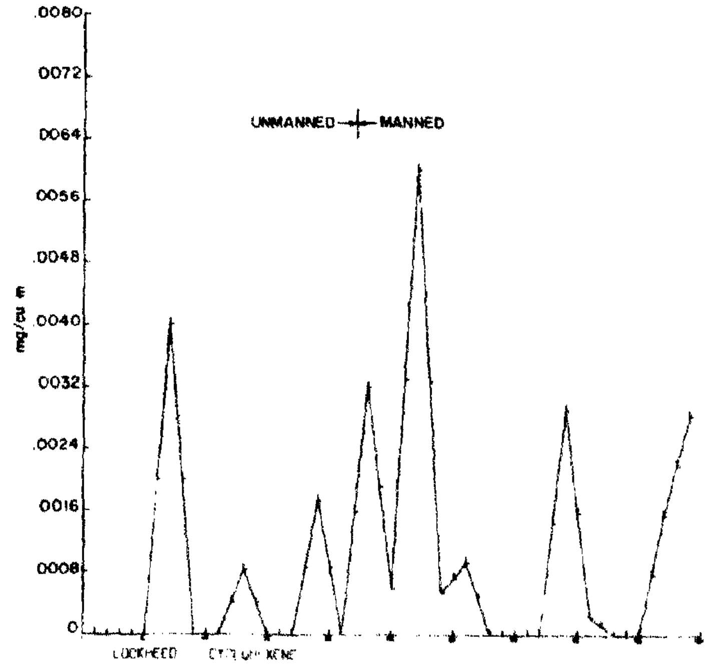

UNMANNED —+— MANNED
LOCKHEED ALLENE
mg/cu m
0
002
004
006
008
010
012
014
016
018
020


UNMANNED —+— MANNED
LOCKHEED 1-PENTENE
mg/cu m
0
0004
0008
0012
0016
0020
0024
0028
0032
0036
0040


UNMANNED
MANNED
0080
0072
0064
0056
0048
0040
0032
0024
0016
0008
0
mg/cu m
LOCKHEED
1, 3-BUTADIENE


UNMANNED
MANNED
040
036
032
028
024
020
016
012
008
004
0
mg/cu m
LOCKHEED
ACETYLENE


.0080
.0072
.0064
.0056
.0048
.0040
.0032
.0024
.0016
.0008
0
mg/cu m
UNMANNED MANNED
LOCKHEED
PROPYNE

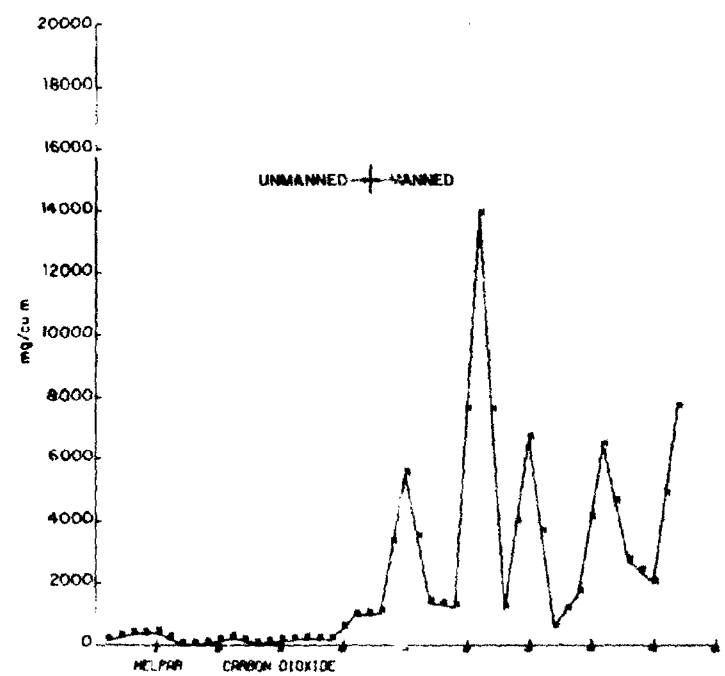

.0080
.0072
.0064
.0056
.0048
.0040
.0032
.0024
.0016
.0008
0
mg/cu m
UNMANNED MANNED
LOCKHEED

APPENDIX III

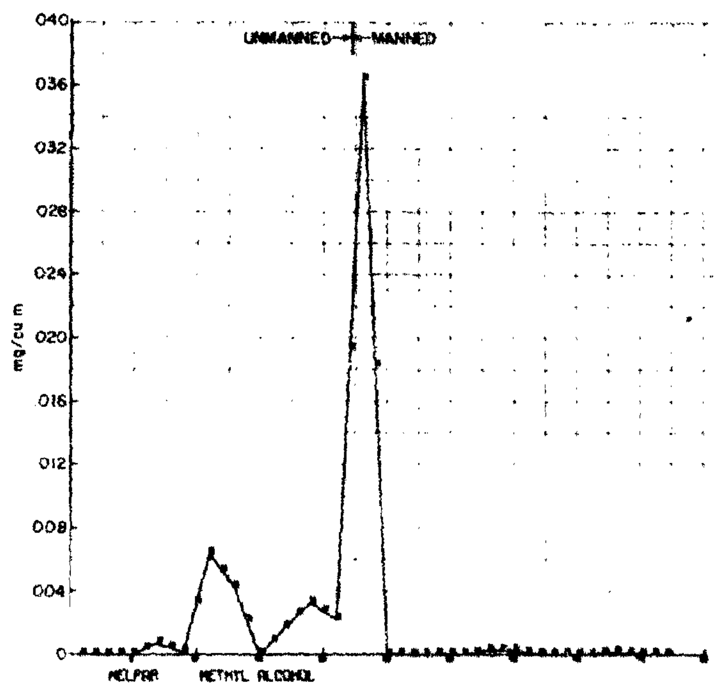
A DETAILED STUDY OF CONTAMINANT PRODUCTION IN A SPACE CABIN SIMULATOR AT 760 MM. HG

Graphic Representation of Compounds (Melpar, Inc.)

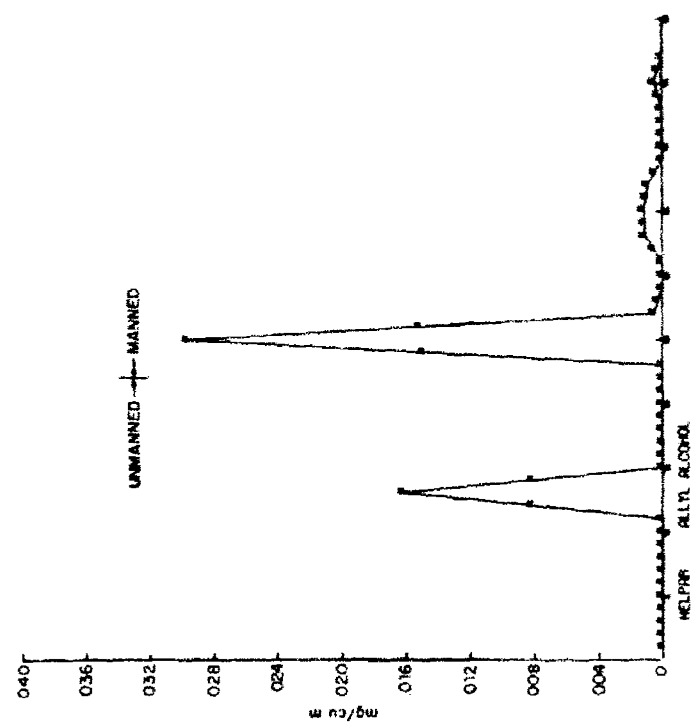
Preceding Page Blank

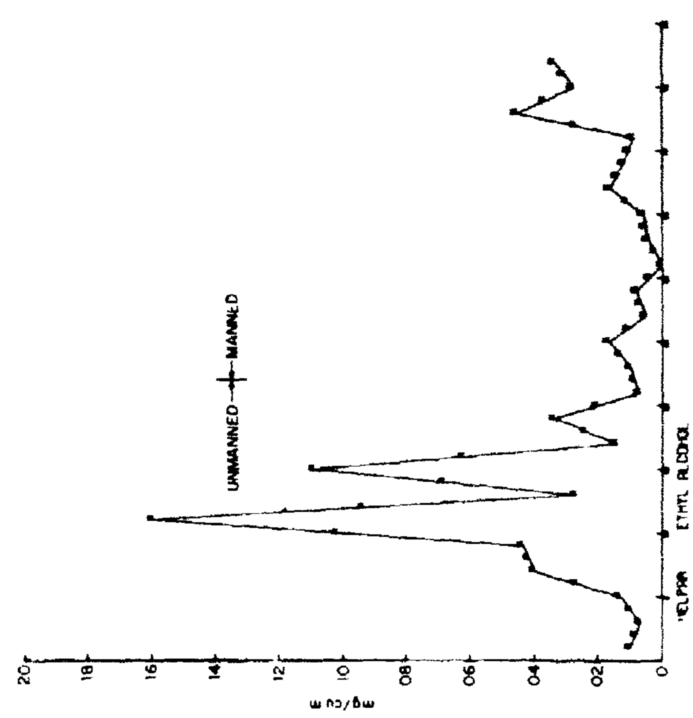


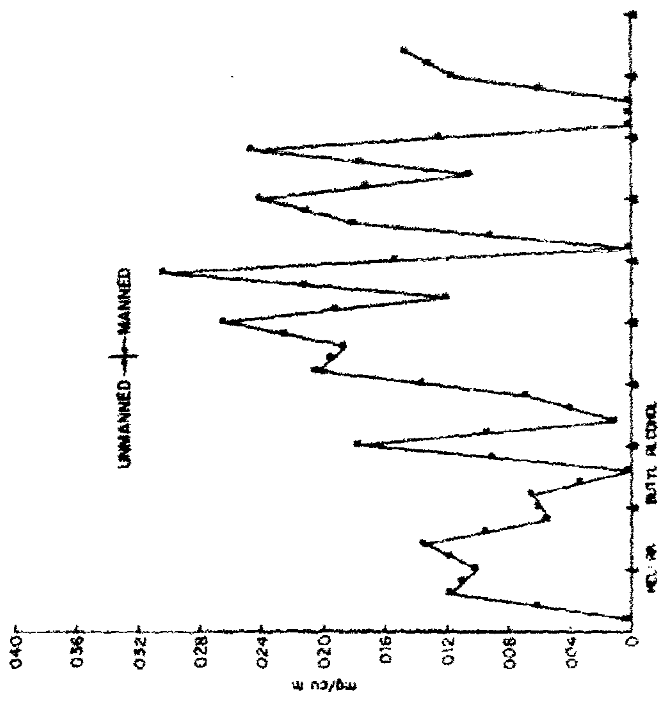
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
mg/cu m
UNMANNED — MANNED
HELPAR
CARBON DIOXIDE

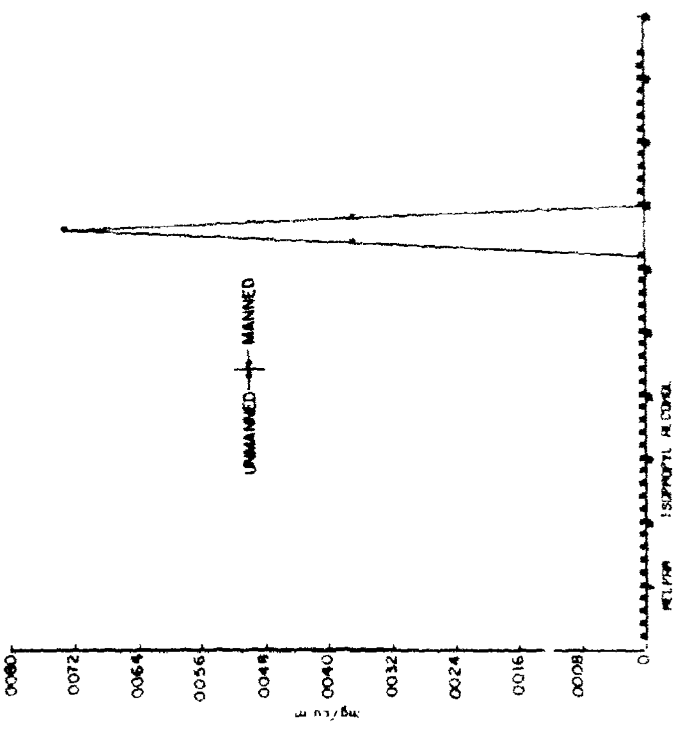


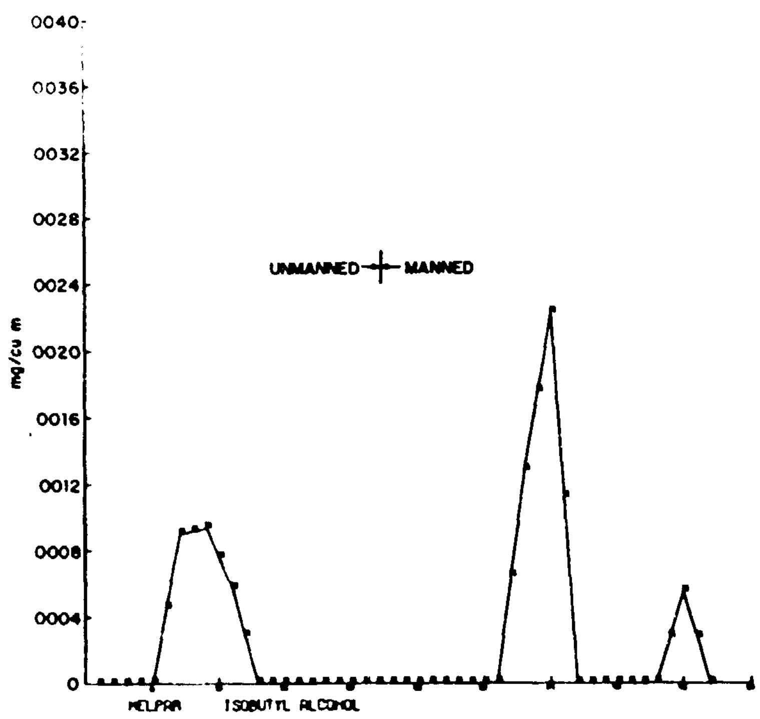
.040
.036
.032
.028
.024
.020
.016
.012
.008
.004
0
mg/cu m
UNMANNED — MANNED
HELPAR
METHYL ALCOHOL

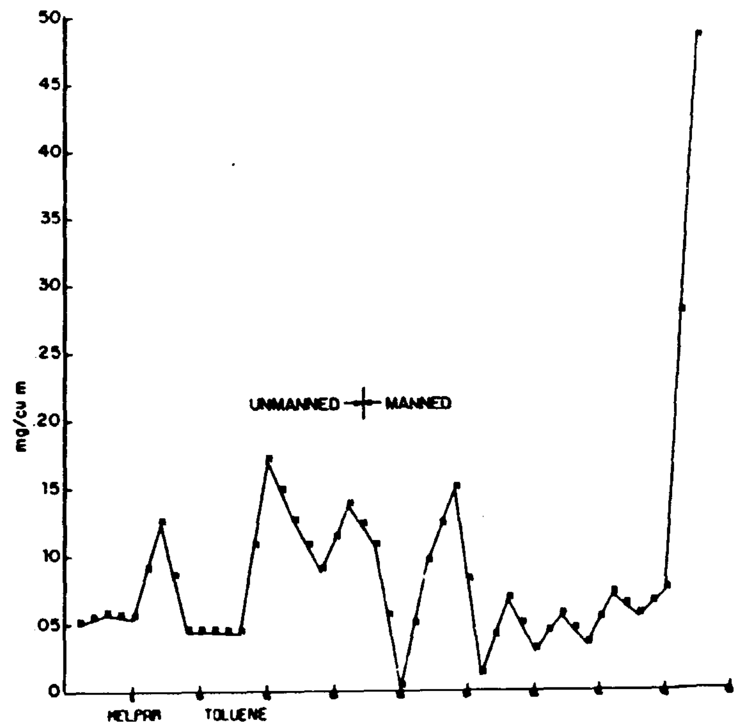

mg/cu m
040
036
032
028
024
020
016
012
008
004
0
UNMANNED —+— MANNED
HELPAR
ALLYL ALCOHOL

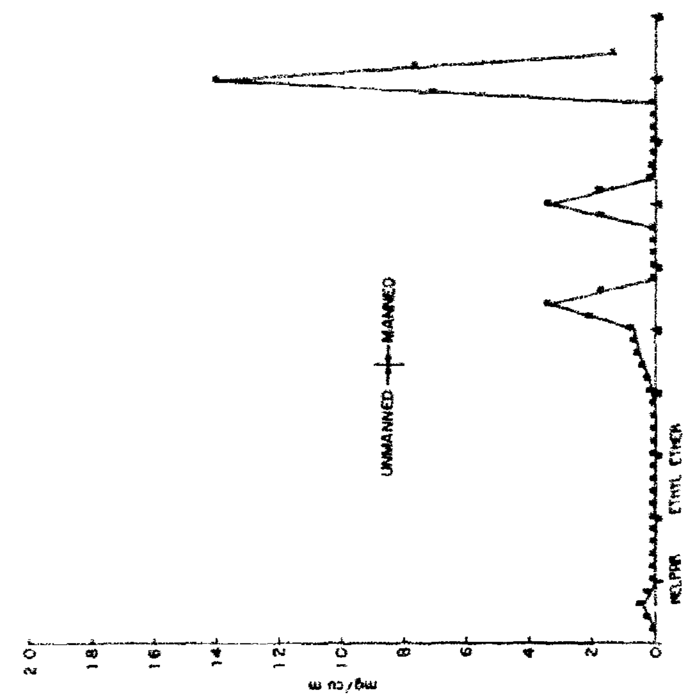

mg/cu m
20
18
16
14
12
10
08
06
04
02
0
UNMANNED —+— MANNED
HELPAR
ETHYL ALCOHOL

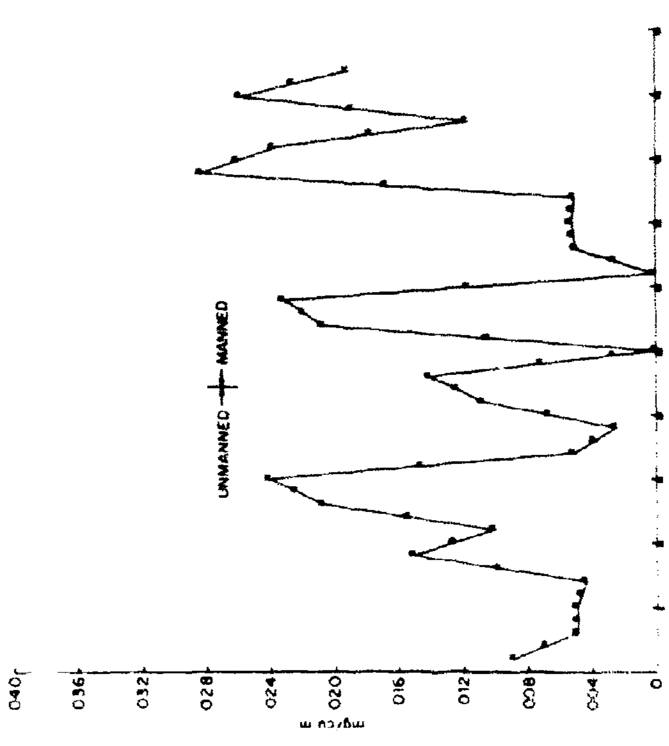

UNMANNED —+— MANNED
BUTYL ALCOHOL
mg/cu m
.040
.036
.032
.028
.024
.020
.016
.012
.008
.004
0

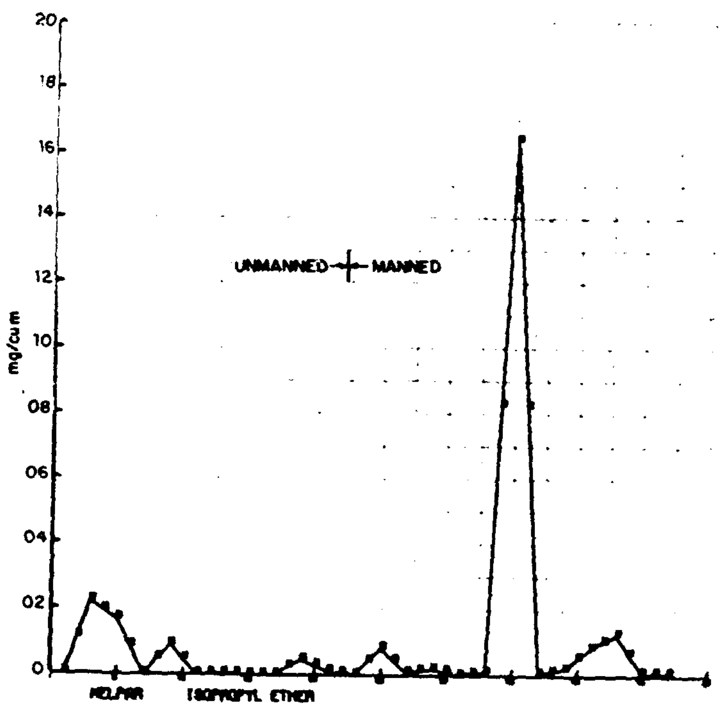

UNMANNED —+— MANNED
ISOPROPYL ALCOHOL
mg/cu m
.0080
.0072
.0064
.0056
.0048
.0040
.0032
.0024
.0016
.0008
0


UNMANNED — MANNED
mg/cu m
0040
0036
0032
0028
0024
0020
0016
0012
0008
0004
0
HELPAR
ISOBUTYL ALCOHOL

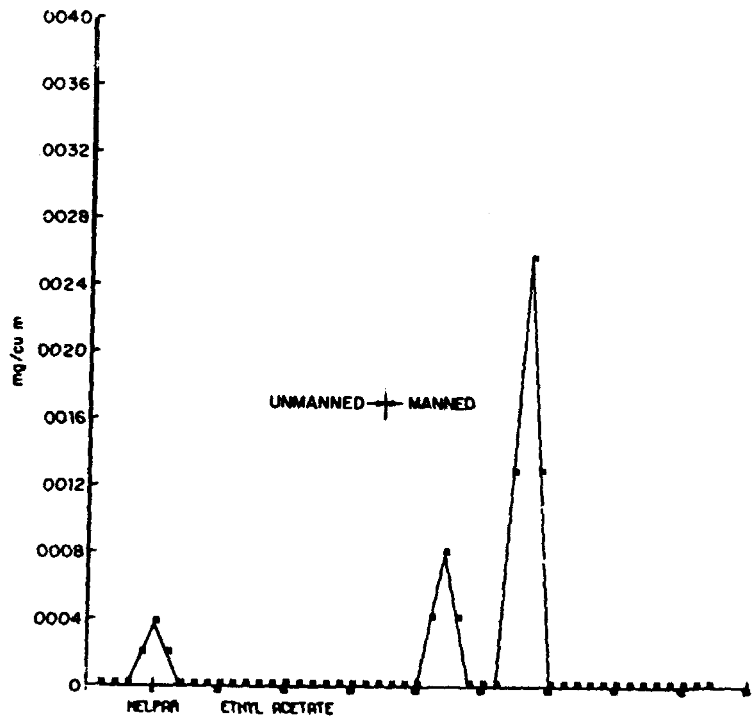

UNMANNED — MANNED
mg/cu m
50
45
40
35
30
25
20
15
10
05
0
HELPAR
TOLUENE


UNMANNED MANNED
HELPER ETHYL ETHER
mg/cu m

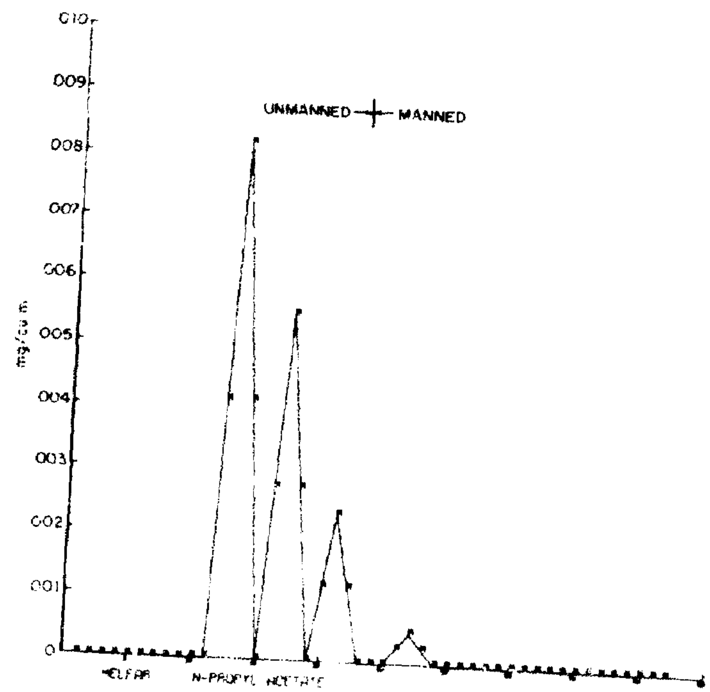

UNMANNED MANNED
HELPER O-XYLENE
mg/cu m



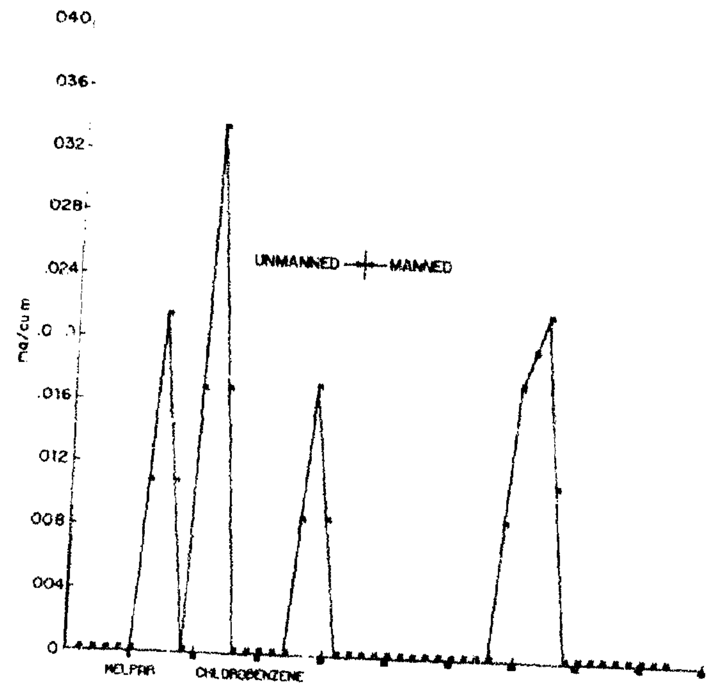
20
18
16
14
12
10
08
06
04
02
0
mg/cu m
UNMANNED MANNED
HELPAR
ISOPROPYL ETHER



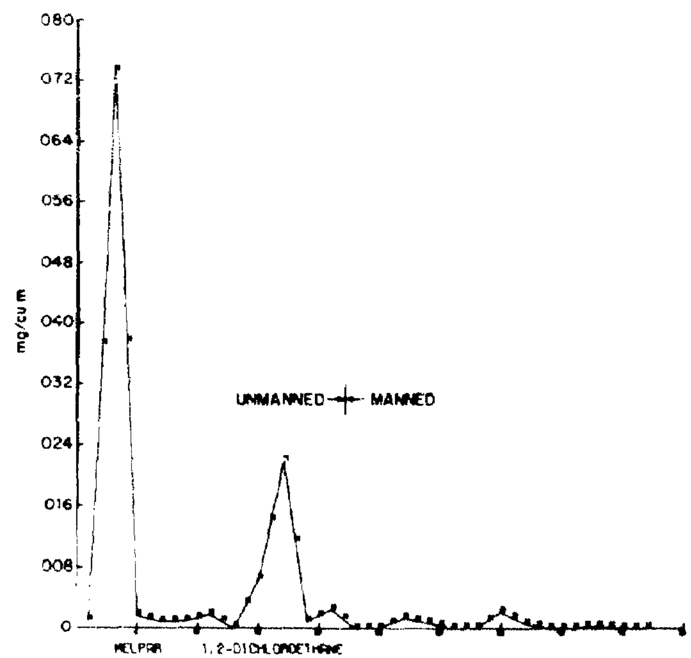
0040
0036
0032
0028
0024
0020
0016
0012
0008
0004
0
mg/cu m
UNMANNED MANNED
HELPAR
ETHYL ACETATE

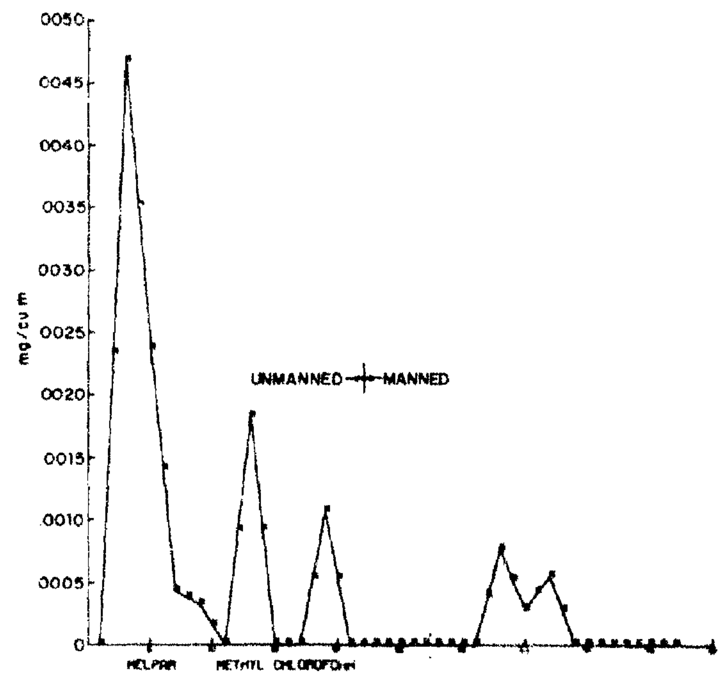


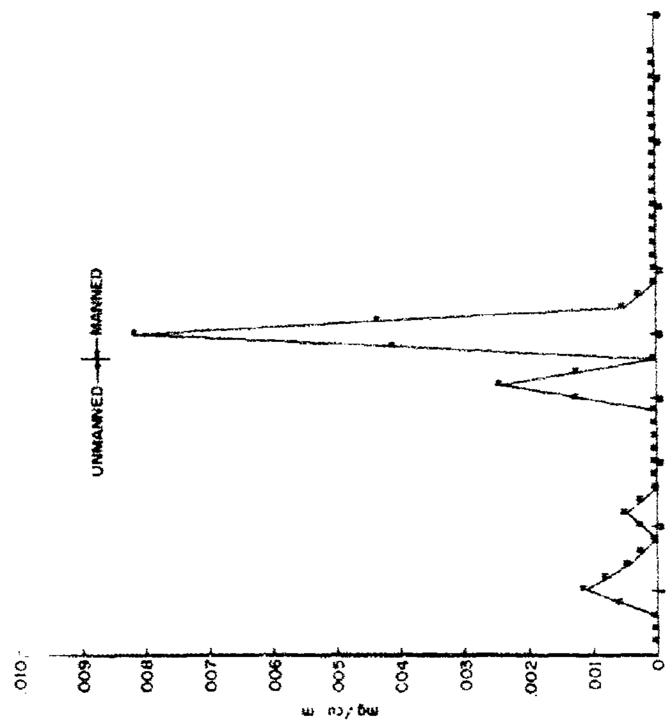
UNMANNED MANNED
mg/cu m
.010
.009
.008
.007
.006
.005
.004
.003
.002
.001
0
MELPAR
N-PROPYL ACETATE

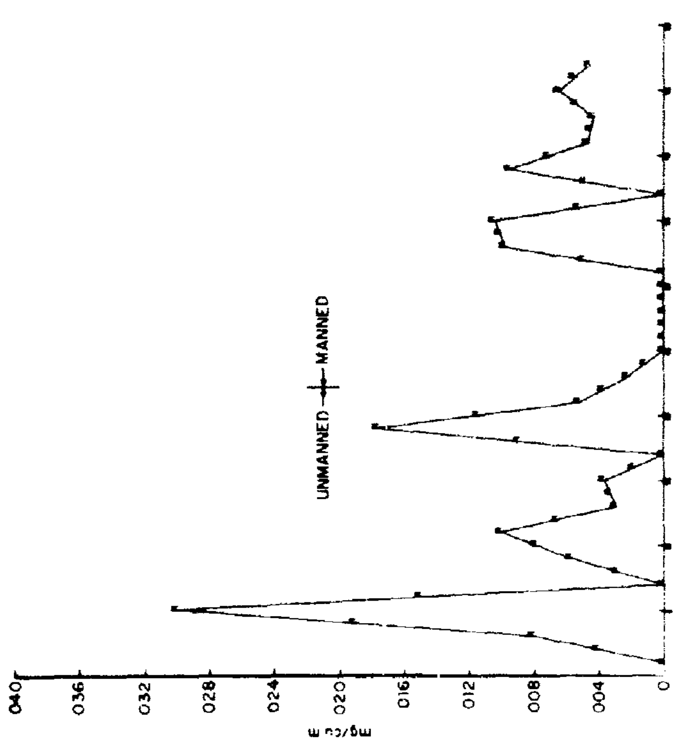


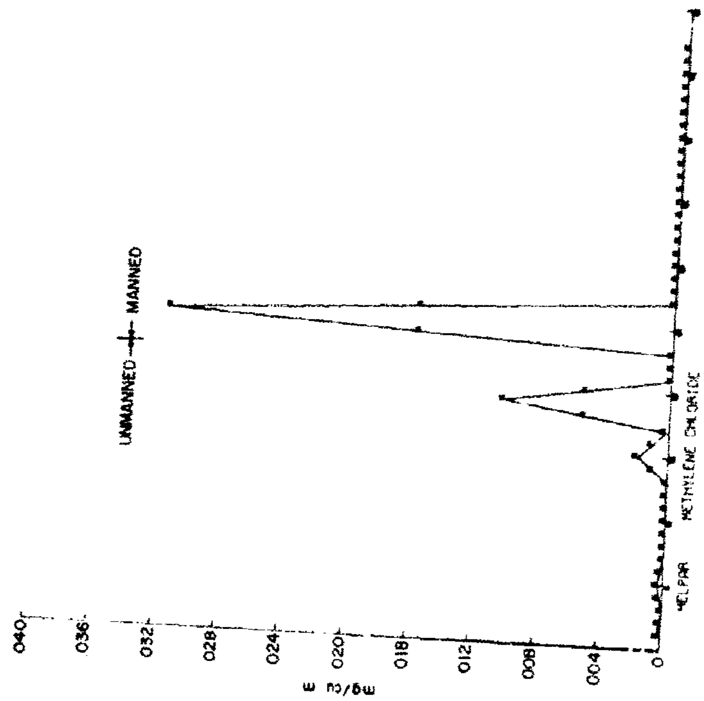
UNMANNED MANNED
mg/cu m
.040
.036
.032
.028
.024
.016
.012
.008
.004
0
MELPAR
CHLOROBENZENE

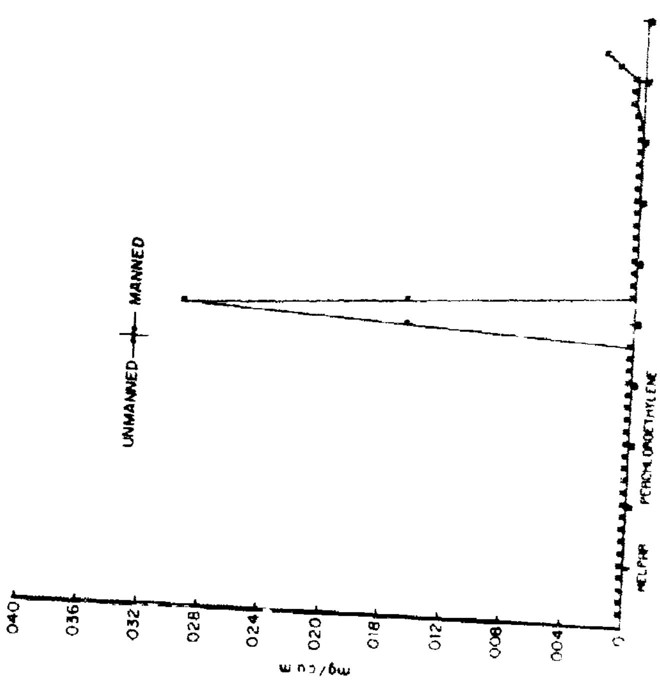

mg/cu m
080
072
064
056
048
040
032
024
016
008
0
UNMANNED MANNED
HELPAR
1,2-DICHLOROETHANE

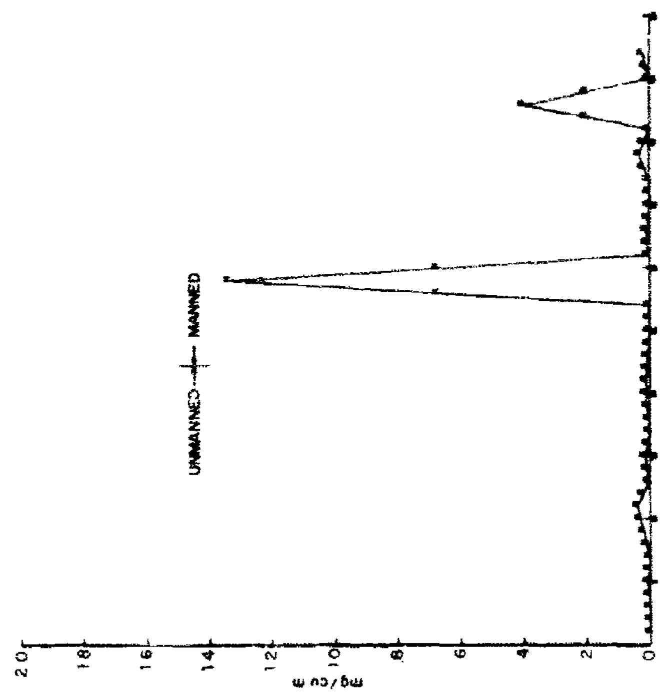

mg/cu m
0050
0045
0040
0035
0030
0025
0020
0015
0010
0005
0
UNMANNED MANNED
HELPAR
METHYL CHLOROFORM


UNMANNED
MANNED
TRICHLOROETHYLENE
HELPAR
mg/cu m
.010
.009
.008
.007
.006
.005
.004
.003
.002
.001
0

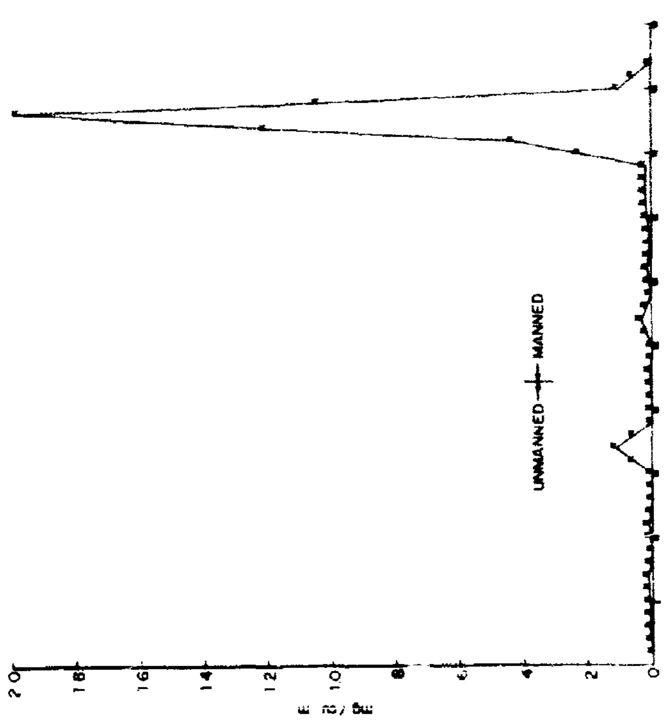

UNMANNED
MANNED
VINYL CHLORIDE
HELPAR
mg/cu m
.040
.036
.032
.028
.024
.020
.016
.012
.008
.004
0


UNMANNED —+— MANNED
mg/cu m
040
036
032
028
024
020
018
012
008
004
0
MELPAR
METHYLENE CHLORIDE

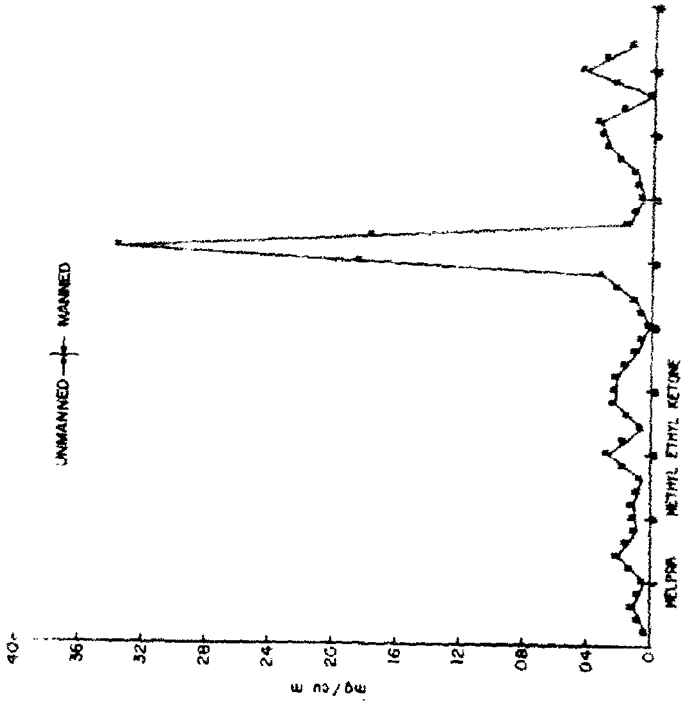

UNMANNED —+— MANNED
mg/cu m
040
036
032
028
024
020
018
012
008
004
0
MELPAR
PERCHLOROETHYLENE



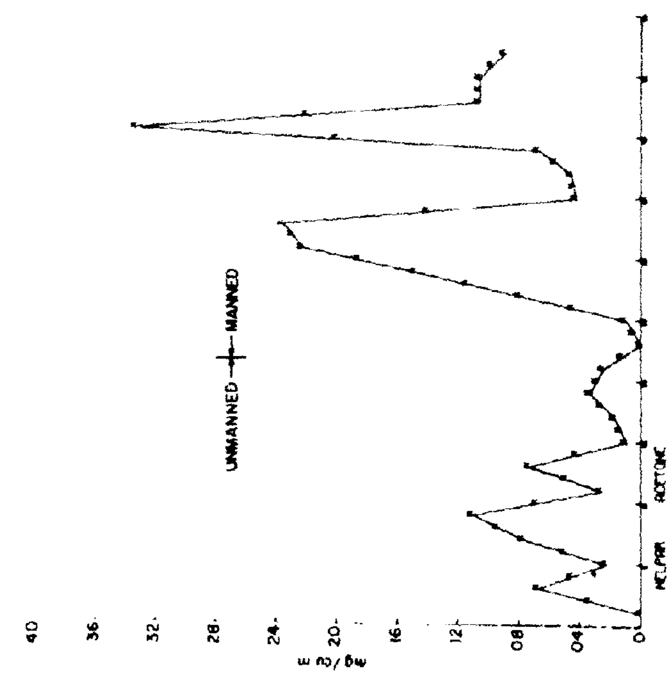
UNMANNED MANNED
mg/cu m
FREON 11



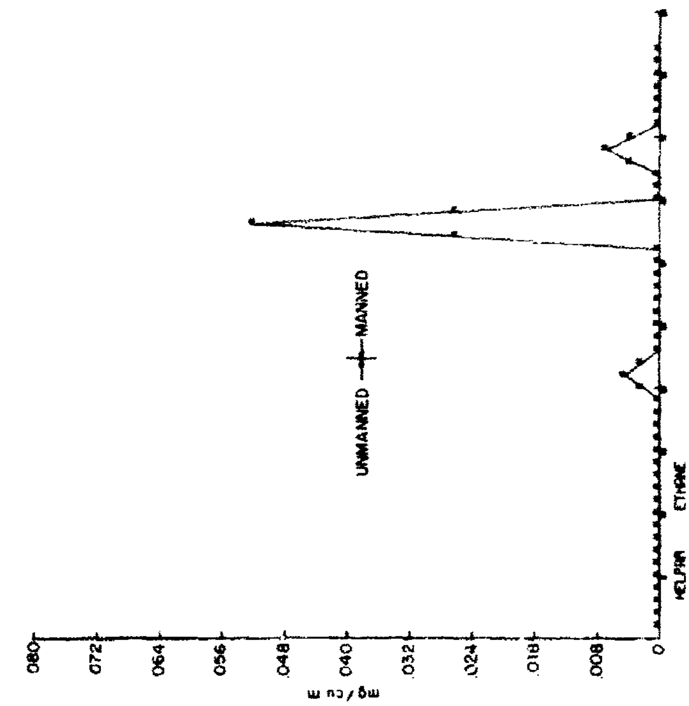
UNMANNED MANNED
mg/cu m
CHLOROFORM



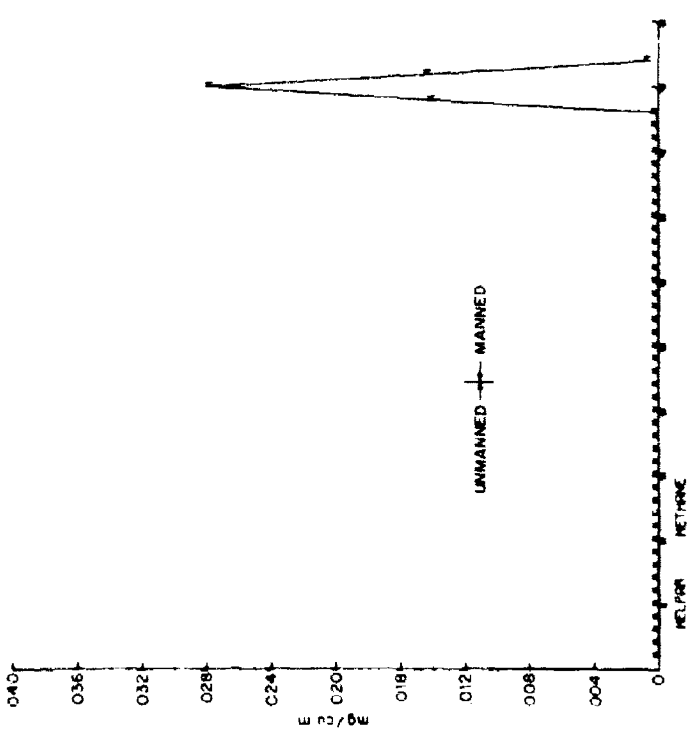
UNMANNED — MANNED
mg/cu m
40
36
32
28
24
20
16
12
08
04
0
MELPAR
METHYL ETHYL KETONE



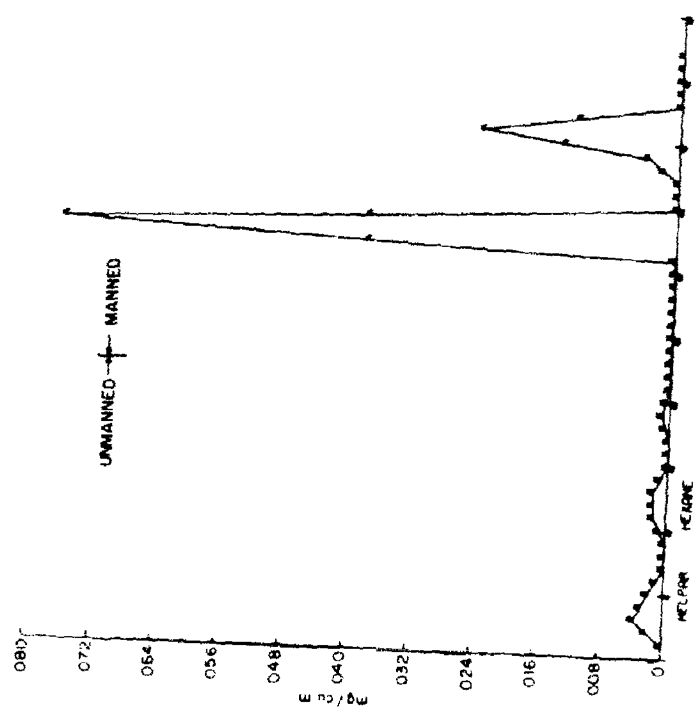
UNMANNED — MANNED
mg/cu m
40
36
32
28
24
20
16
12
08
04
0
MELPAR
ACETONE

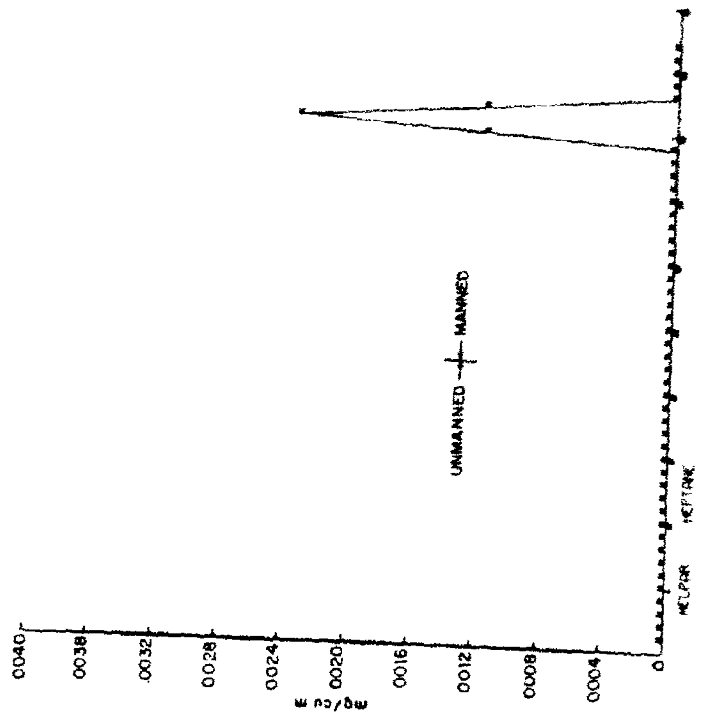


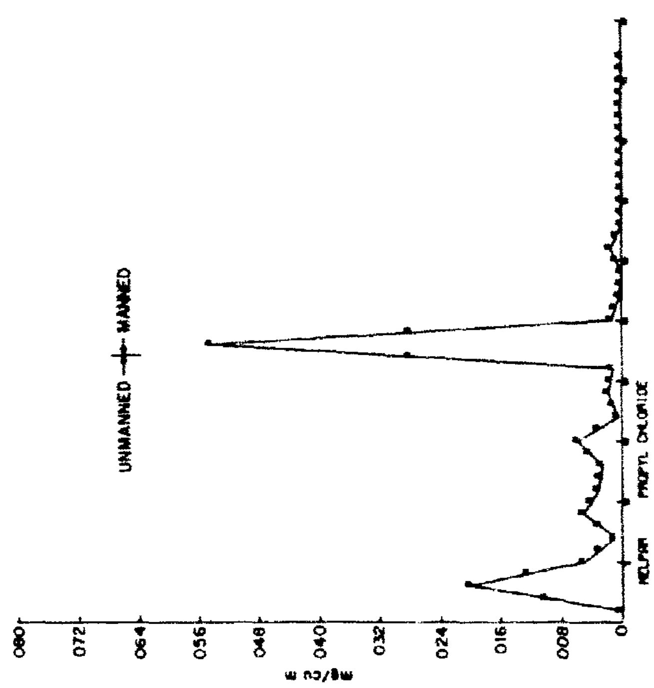
mg/cu m
.080
.072
.064
.056
.048
.040
.032
.024
.018
.008
0
UNMANNED
MANNED
HELPAR
ETHANE



mg/cu m
.040
.036
.032
.028
.024
.020
.018
.012
.008
.004
0
UNMANNED
MANNED
HELPAR
METHANE


UNMANNED
MANNED
mg/cu m
080
072
064
056
048
040
032
024
016
008
0
HELPAR
HEXANE

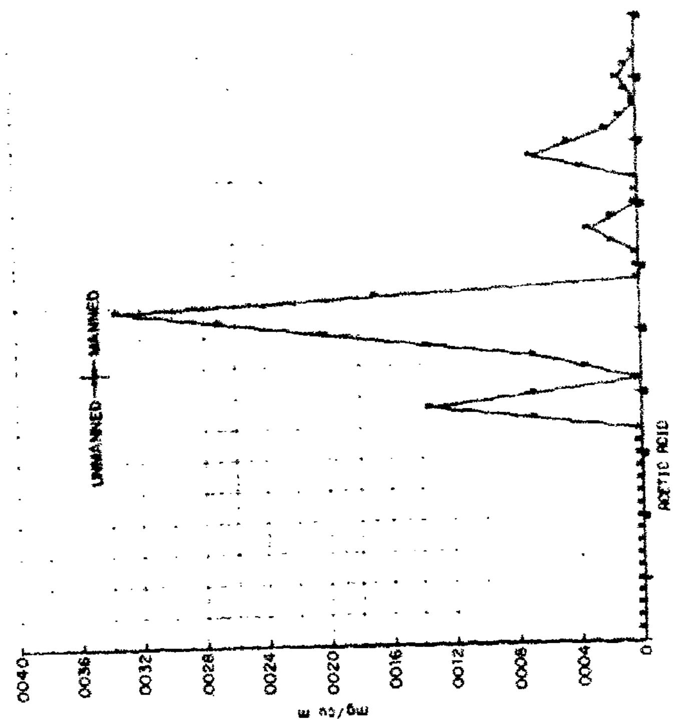

UNMANNED
MANNED
mg/cu m
0040
0032
0028
0024
0020
0016
0012
0008
0004
0
HELPAR
HEPTANE

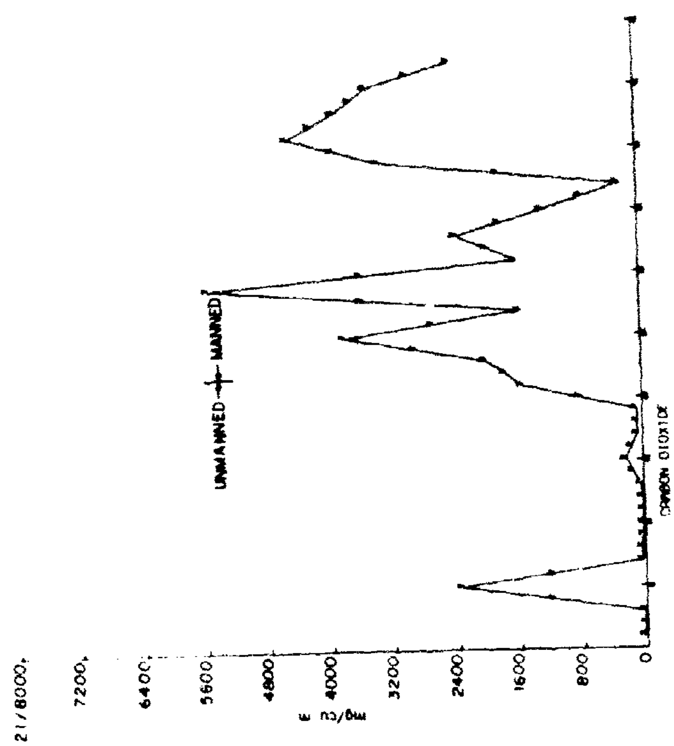

UNMANNED
MANNED
mg/cu m
080
072
064
056
048
040
032
024
016
008
0
MELPAR
PROPYL CHLORIDE

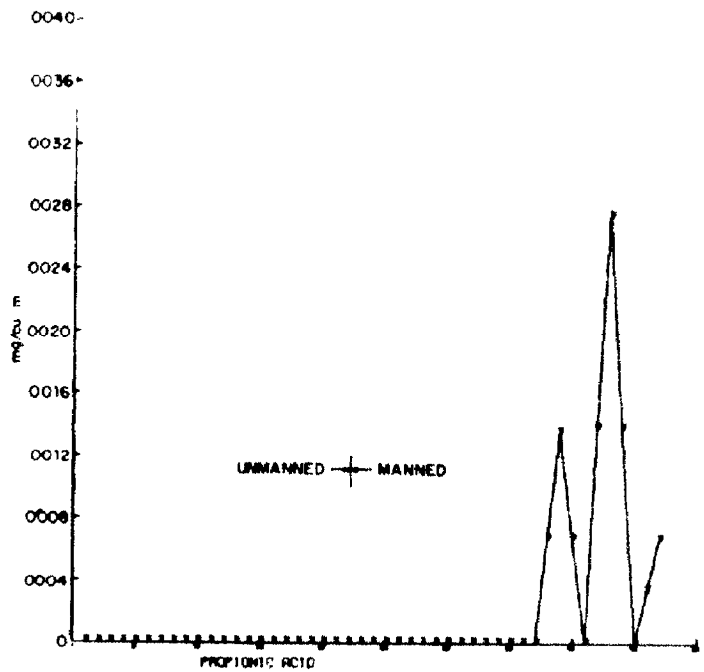
APPENDIX IV

A DETAILED STUDY OF CONTAMINANT PRODUCTION IN A SPACE CABIN SIMULATOR AT 760 MM. HG

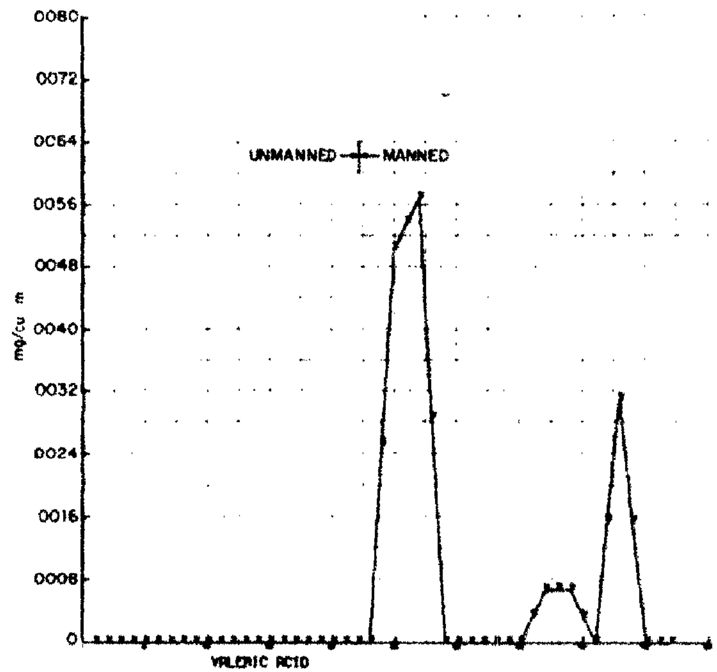
Graphic Representation of Compounds
(Aerojet-General)


UNMANNED — MANNED
ACETIC ACID
mg/cu m
.0040
.0036
.0032
.0028
.0024
.0020
.0016
.0012
.0008
.0004
0

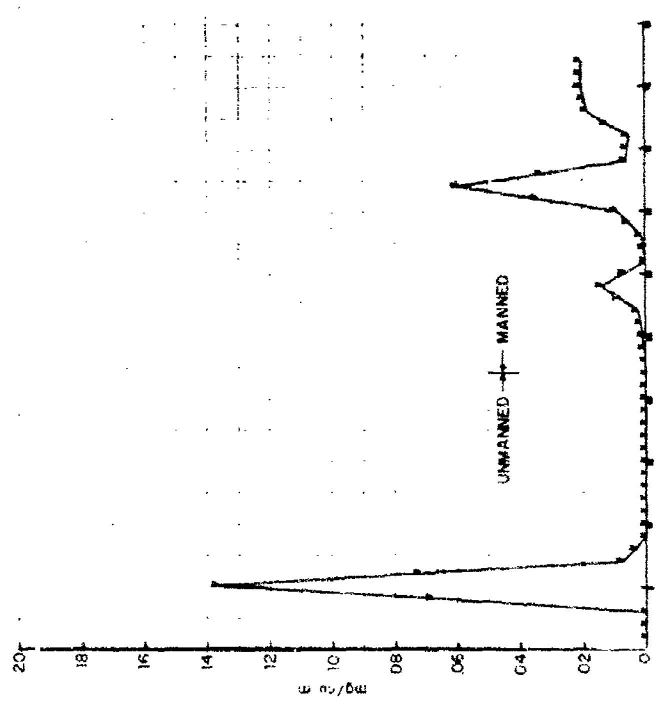

UNMANNED — MANNED
CARBON DIOXIDE
mg/cu m
7200
6400
5600
4800
4000
3200
2400
1600
800
0

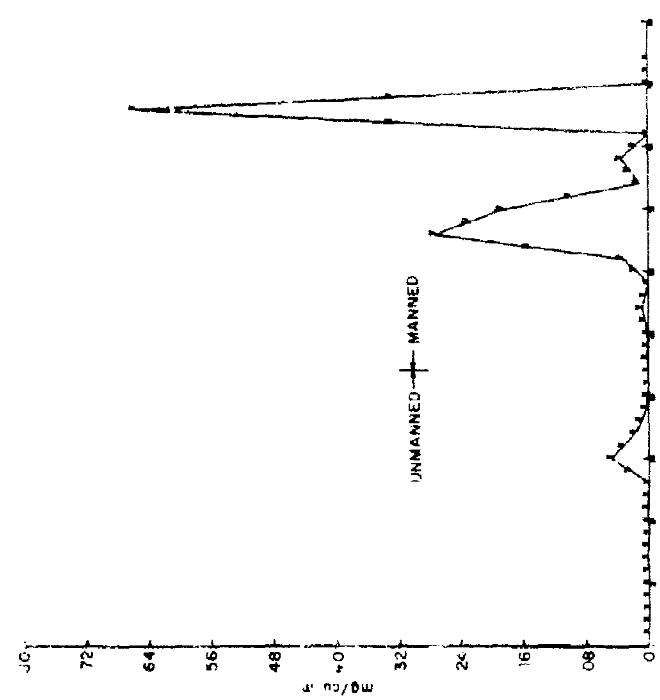


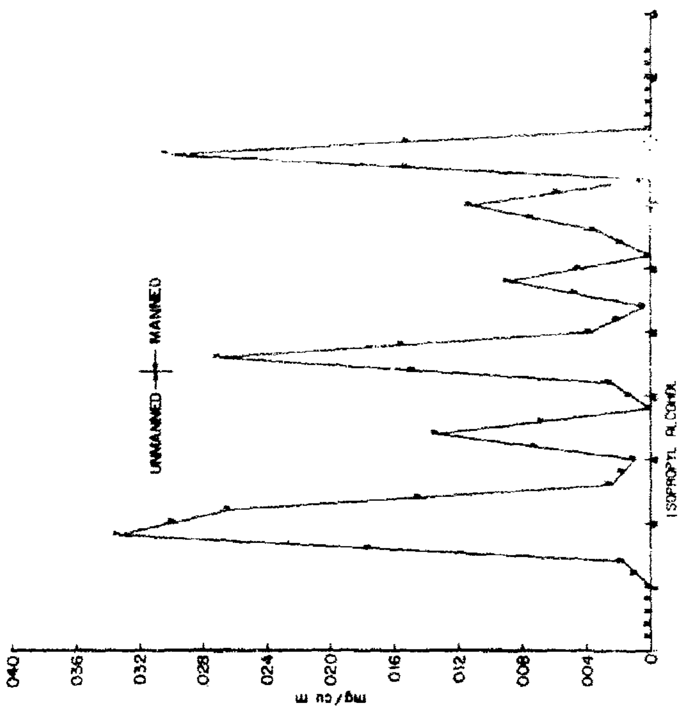
0040
0036
0032
0028
0024
0020
0016
0012
0008
0004
0
mg/cu m
UNMANNED MANNED
PROPIONIC ACID

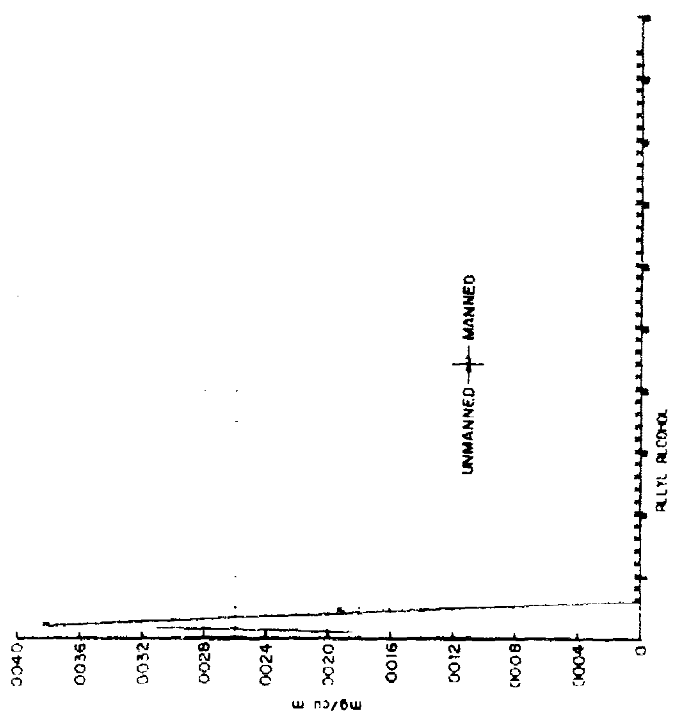


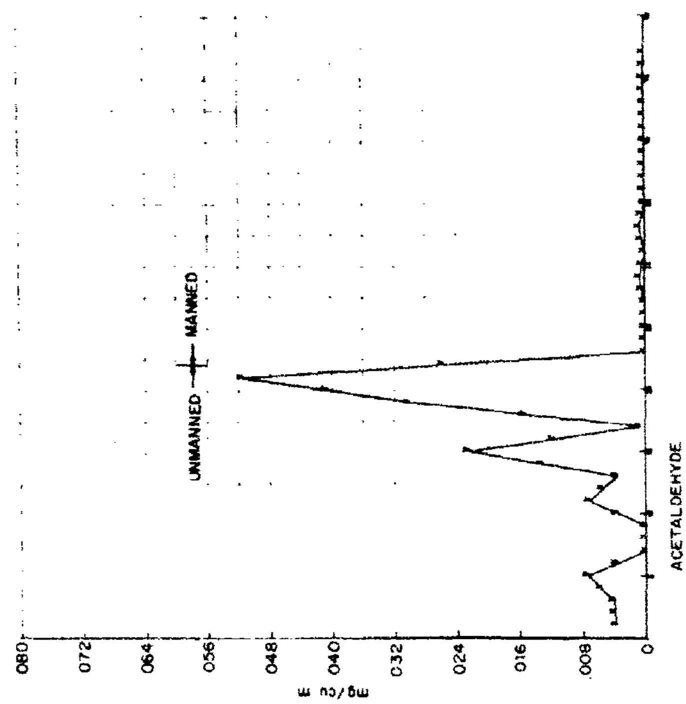
0080
0072
0064
0056
0048
0040
0032
0024
0016
0008
0
mg/cu m
UNMANNED MANNED
VALERIC ACID

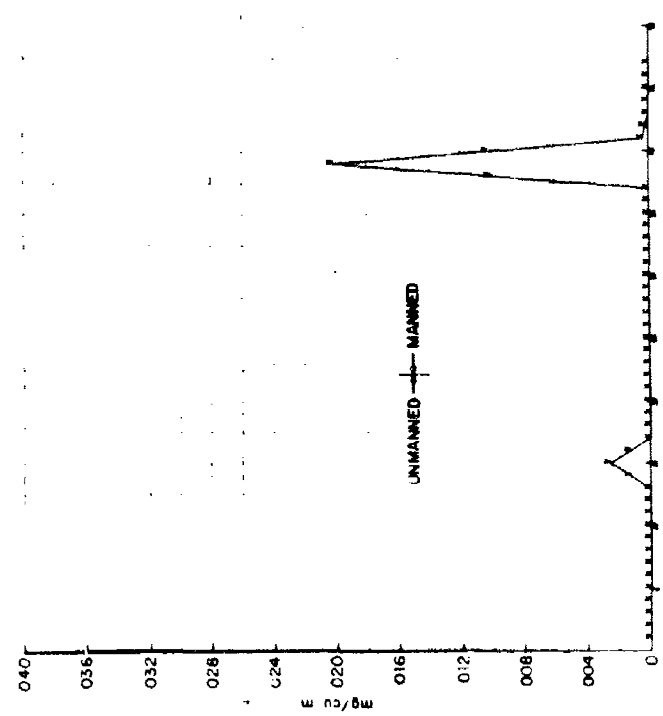

UNMANNED
MANNED
ETHYL ALCOHOL
mg/cu m
20
18
16
14
12
10
08
06
04
02
0

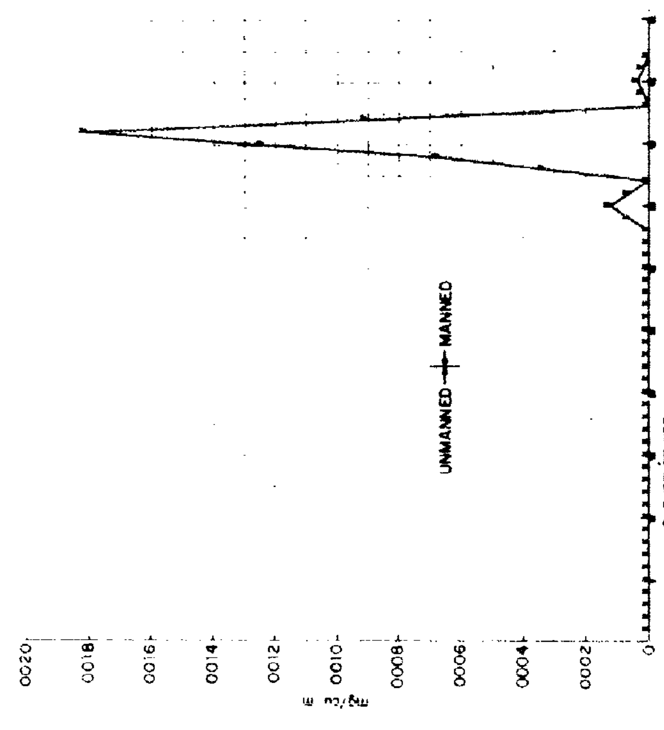

UNMANNED
MANNED
METHYL ALCOHOL
72
64
56
48
32
24
16
08
0


UNMANNED MANNED
ISOPROPYL ALCOHOL
mg/cu m
040
036
032
028
024
020
016
012
008
004
0

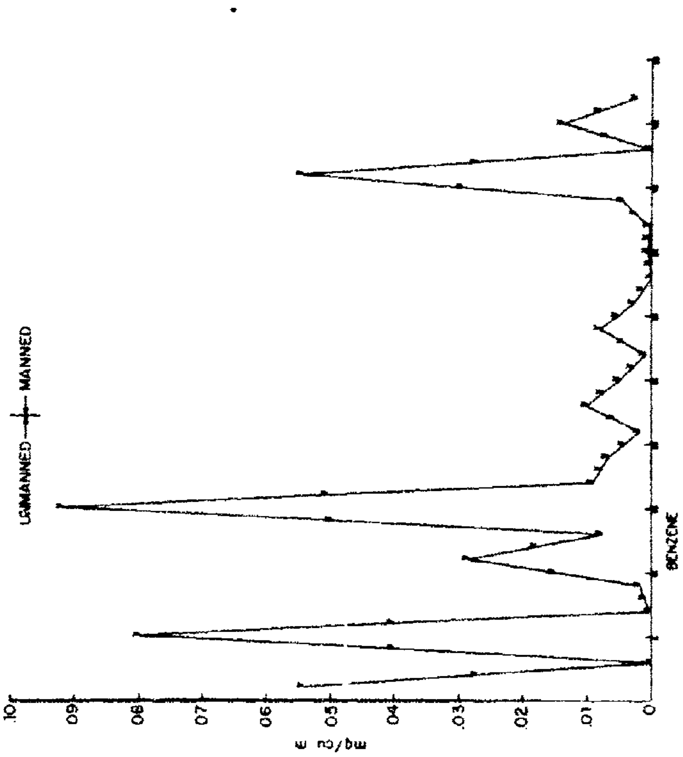

UNMANNED MANNED
ALLYL ALCOHOL
mg/cu m
0040
0036
0032
0028
0024
0020
0016
0012
0008
0004
0


UNMANNED
MANNED
ACETALDEHYDE
mg/cu m
080
072
064
056
048
040
032
024
016
008
0

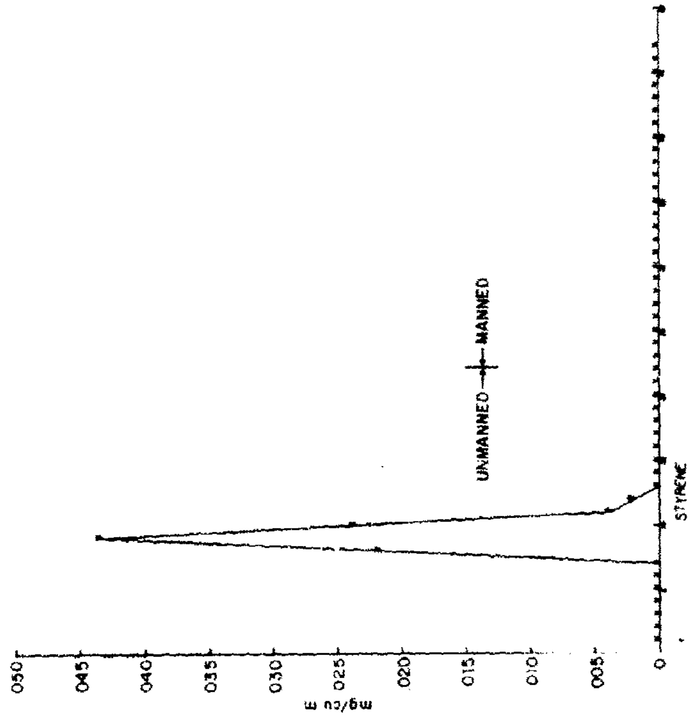

UNMANNED
MANNED
ISOBUTYL ALCOHOL
mg/cu m
040
036
032
028
024
020
016
012
008
004
0

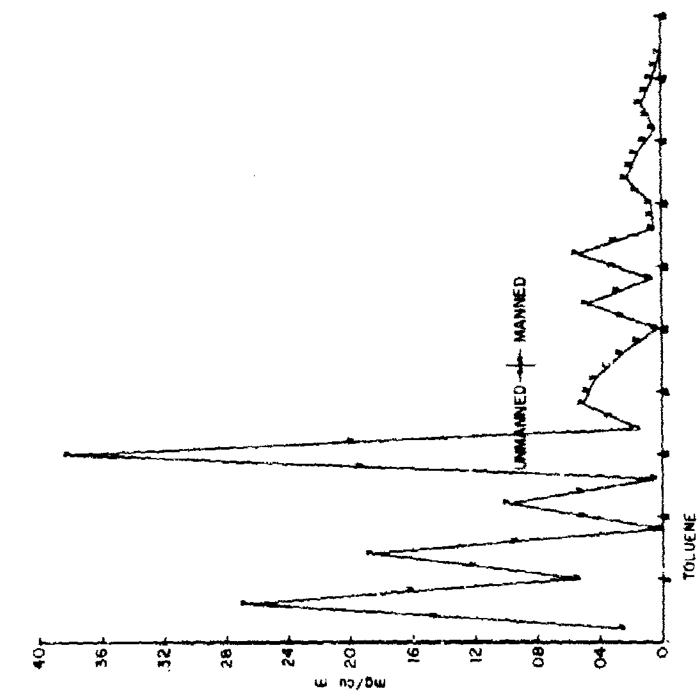


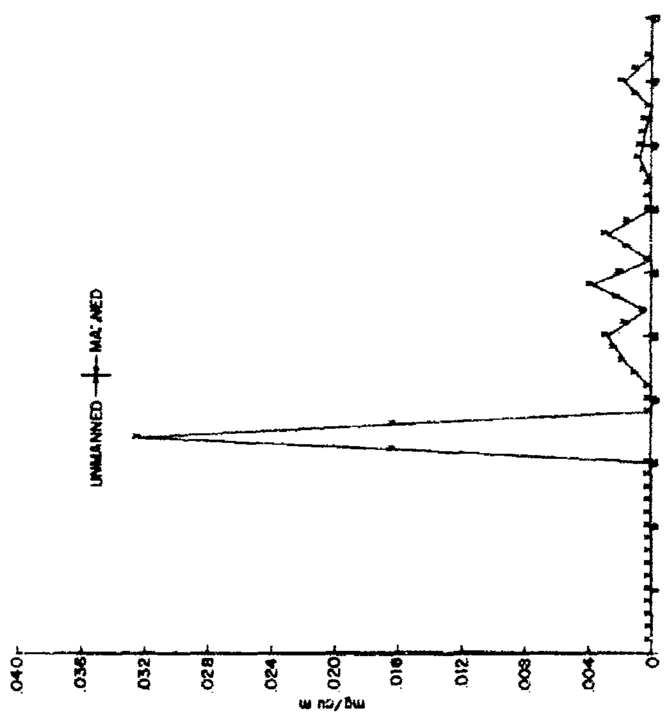
0020
0018
0016
0014
0012
0010
0008
0006
0004
0002
0
mg/cu m
UNMANNED —+— MANNED
BUTYRALDEHYDE

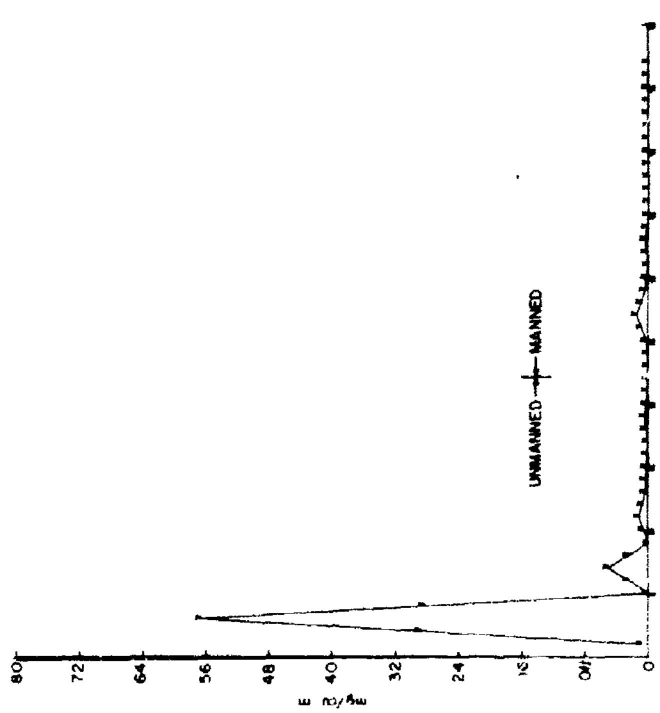


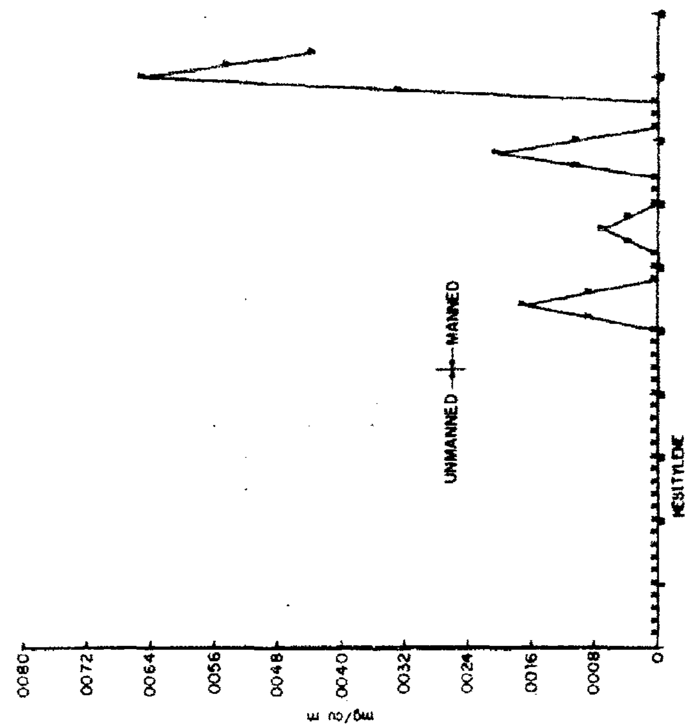
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
0
mg/cu m
UNMANNED —+— MANNED
BENZENE


UNMANNED
MANNED
STYRENE
mg/cu m
050
045
040
035
030
025
020
015
010
005
0

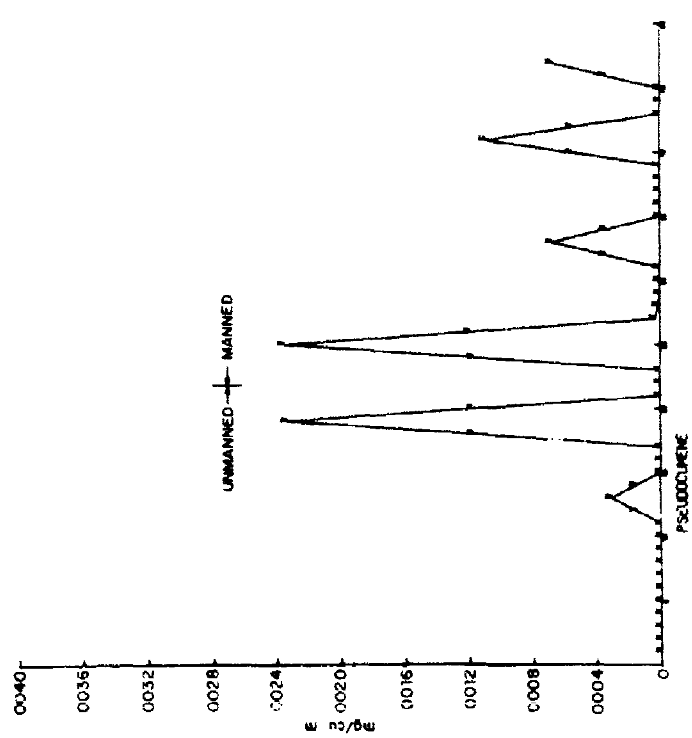

UNMANNED
MANNED
TOLUENE
mg/cu m
40
36
32
28
24
20
16
12
08
04
0


UNMANNED
MA' NED
ETHYL BENZENE
mg/cu m
.040
.036
.032
.028
.024
.020
.016
.012
.008
.004
0

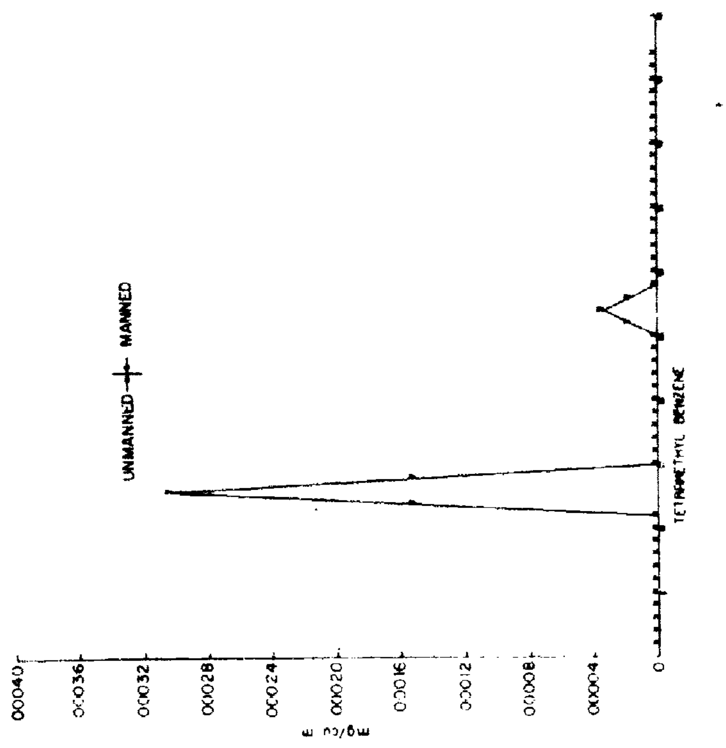

UNMANNED
MANNED
O-XYLENE
mg/cu m
80
72
64
56
48
40
32
24
16
8
0



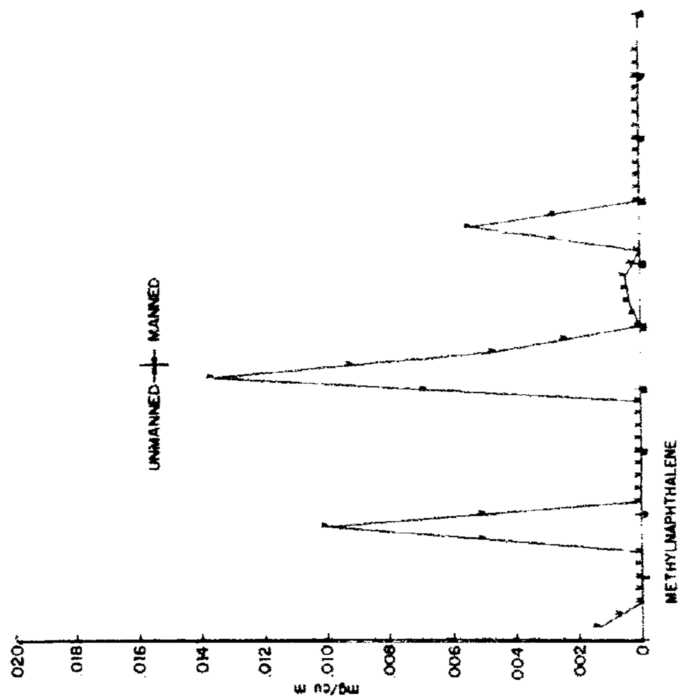
mg/cu m
0080
0072
0064
0056
0048
0040
0032
0024
0016
0008
0
UNMANNED MANNED
MESITYLENE



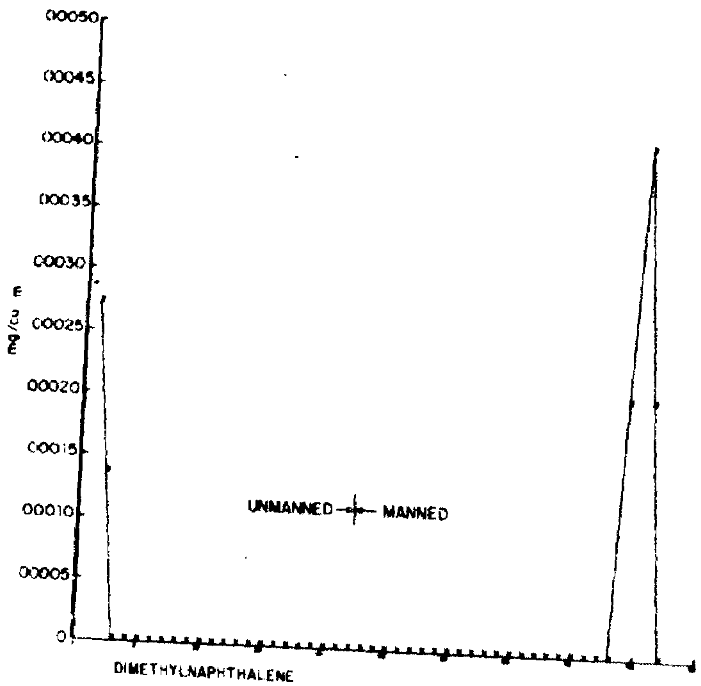
mg/cu m
0040
0036
0032
0028
0024
0020
0016
0012
0008
0004
0
UNMANNED MANNED
PSEUDOCUMENE



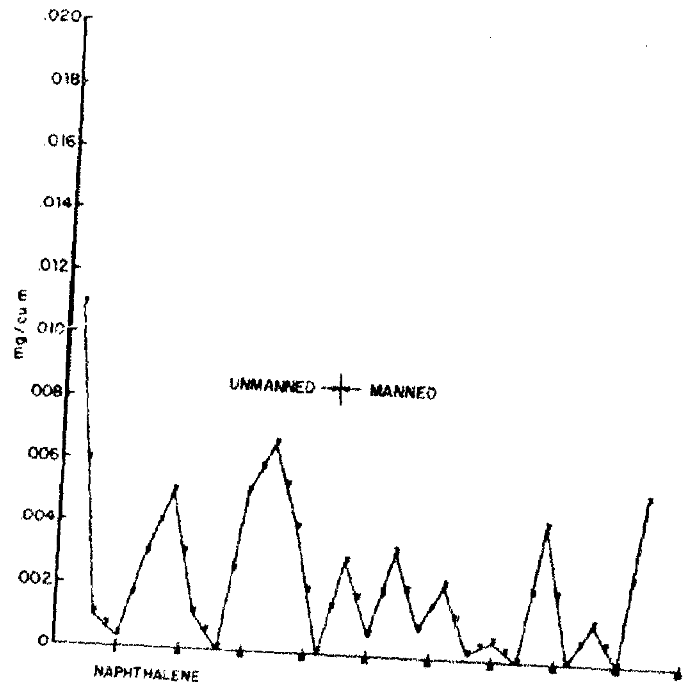
.00040
.00036
.00032
.00028
.00024
.00020
.00016
.00012
.00008
.00004
0
mg/cu m
UNMANNED MANNED
TETRAMETHYL BENZENE



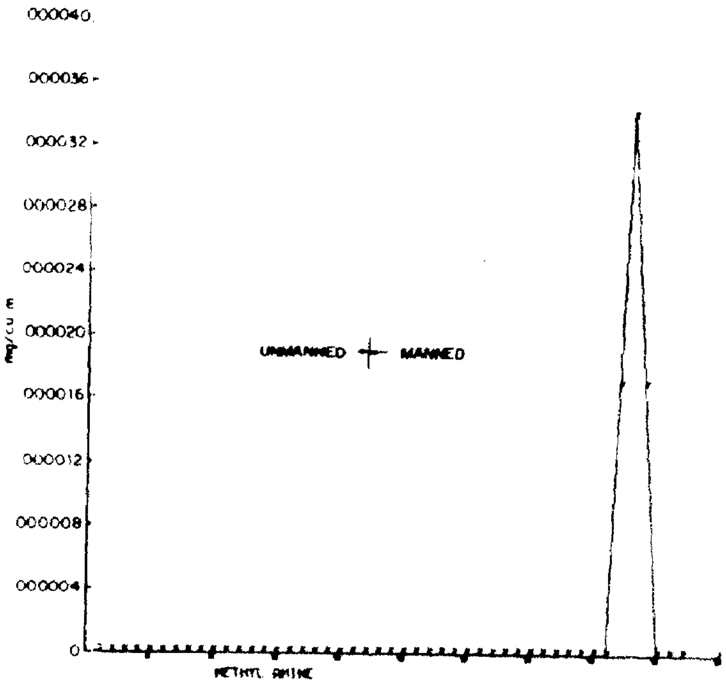
.020
.018
.016
.014
.012
.010
.008
.006
.004
.002
0
mg/cu m
UNMANNED MANNED
METHYLNAPHTHALENE

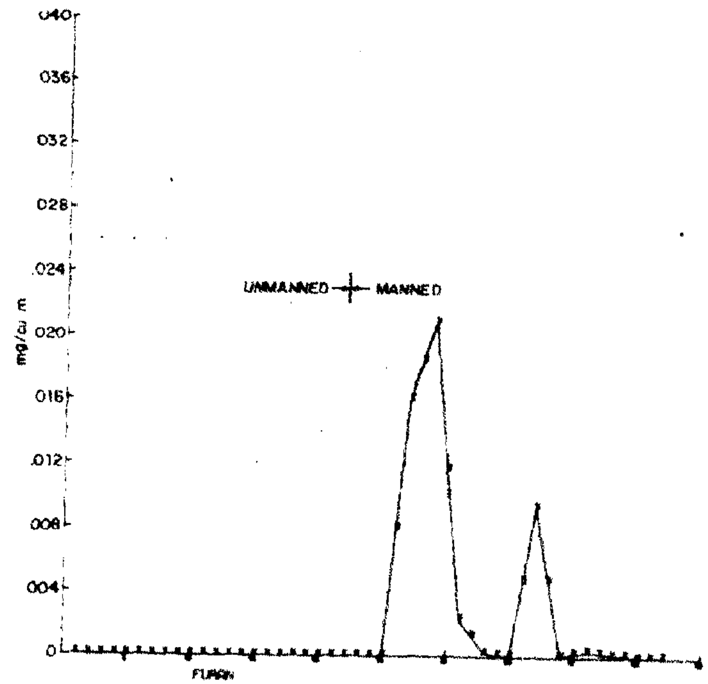


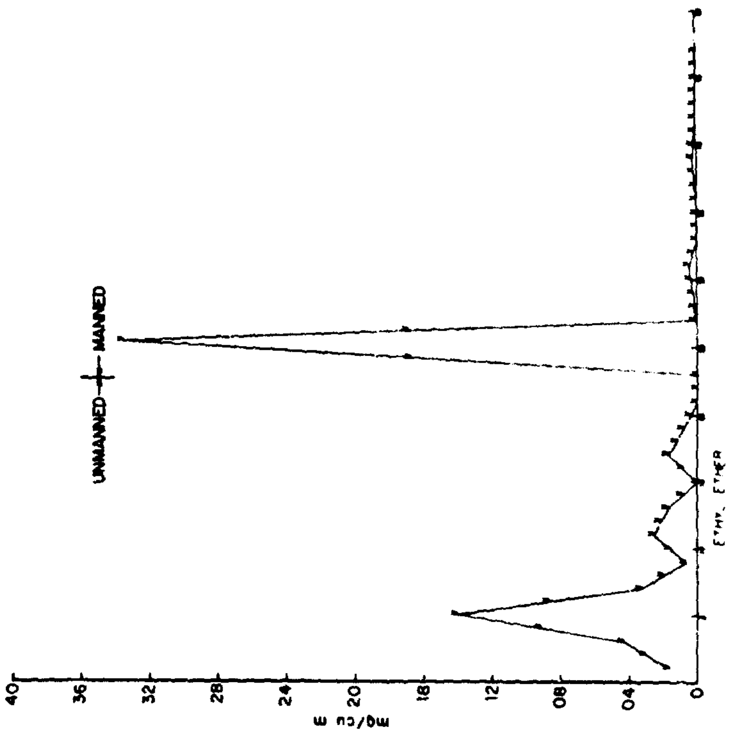
mg/cu m
.00050
.00045
.00040
.00035
.00030
.00025
.00020
.00015
.00010
.00005
0
UNMANNED MANNED
DIMETHYLNAPHTHALENE

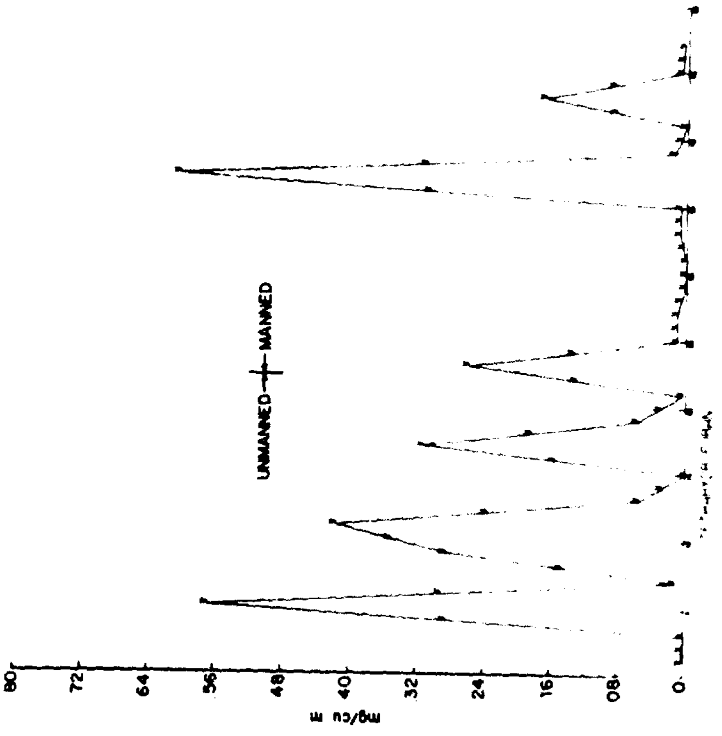


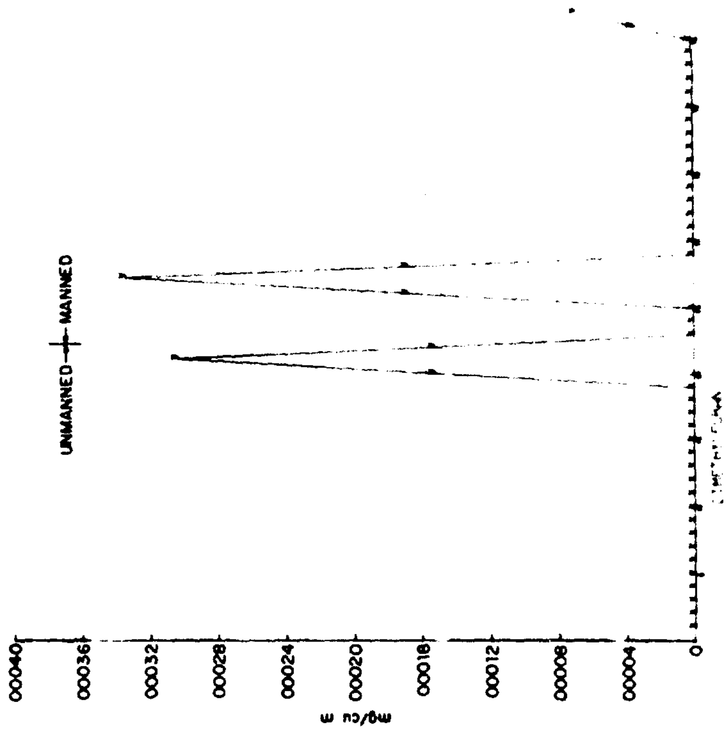
mg/cu m
.020
.018
.016
.014
.012
.010
.008
.006
.004
.002
0
UNMANNED MANNED
NAPHTHALENE


000040
000036
000032
000028
000024
000020
000016
000012
000008
000004
0
mg/cu m
UNMANNED MANNED
METHYL AMINE


.040
.036
.032
.028
.024
.020
.016
.012
.008
.004
0
mg/cu m
UNMANNED MANNED
FURAN


UNMANNED — MANNED
mg/cu m
40
36
32
28
24
20
16
12
08
04
0
ETHYL ETHER


UNMANNED — MANNED
mg/cu m
80
72
64
56
48
40
32
24
16
08
0


UNMANNED
MANNED
mg/cu m
00040
00036
00032
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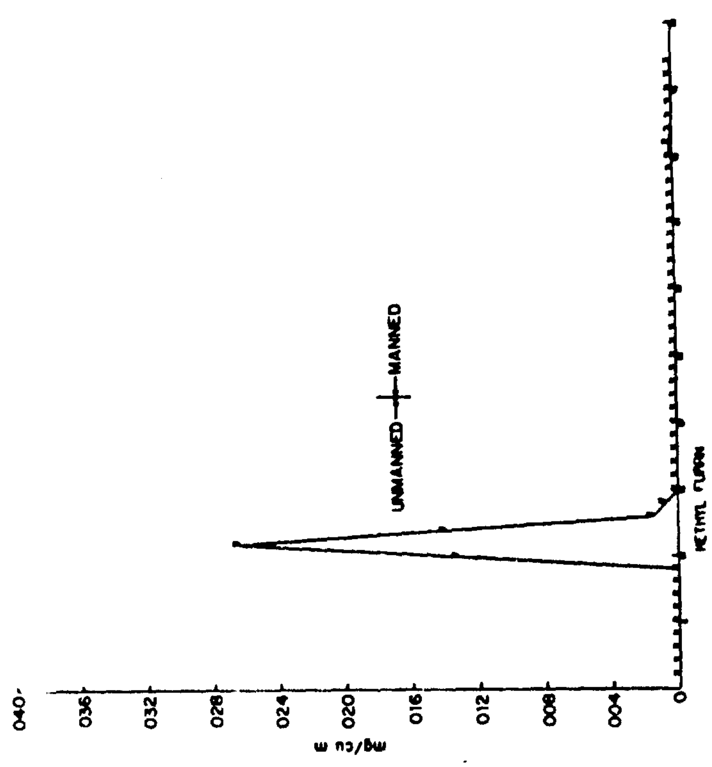
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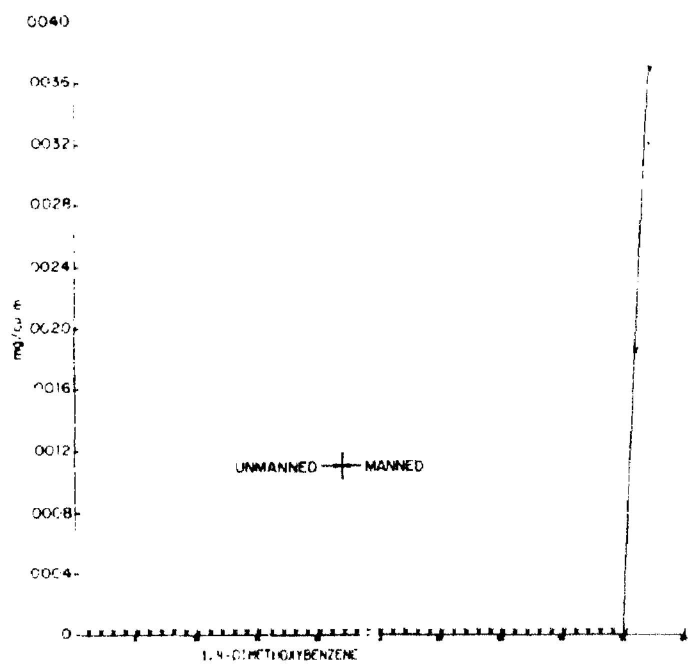
0040
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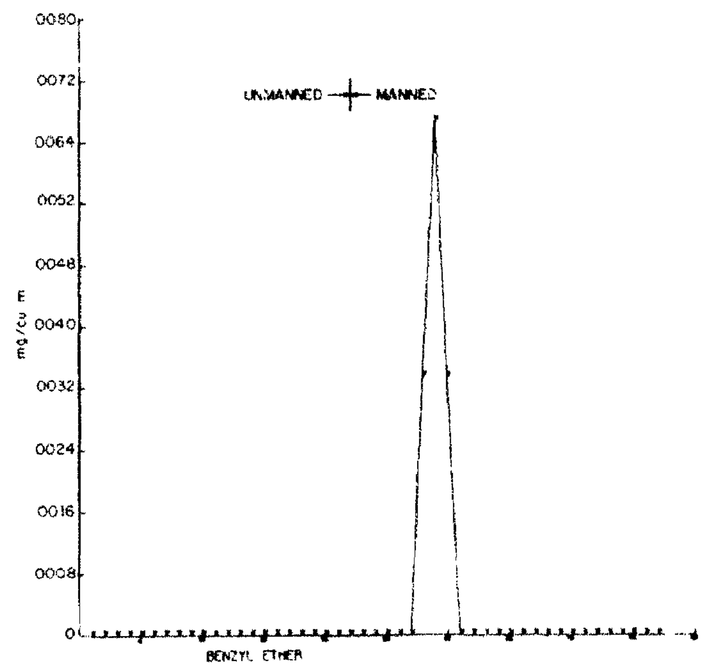
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mg/cu m
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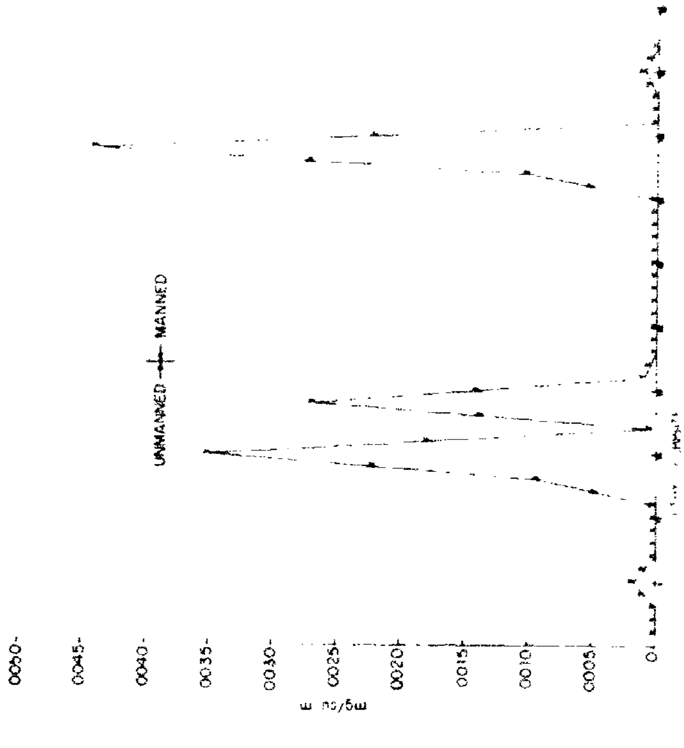
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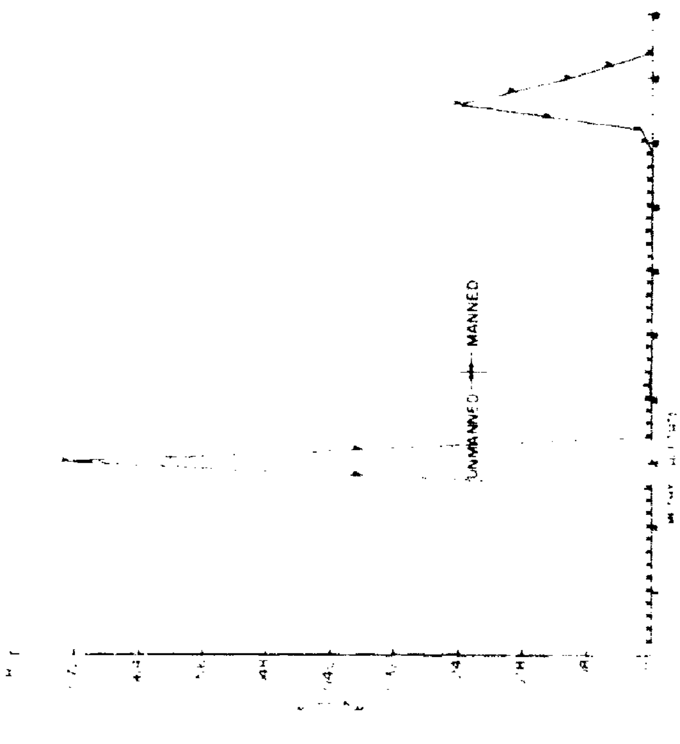

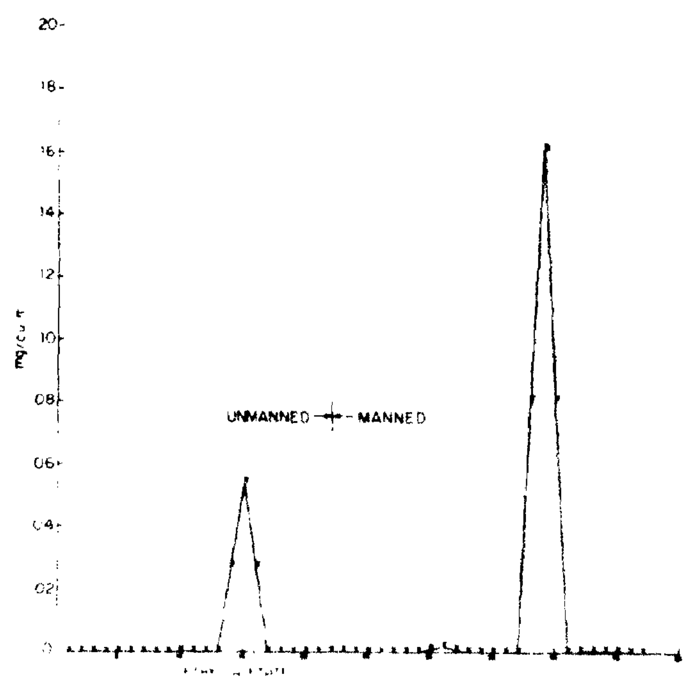

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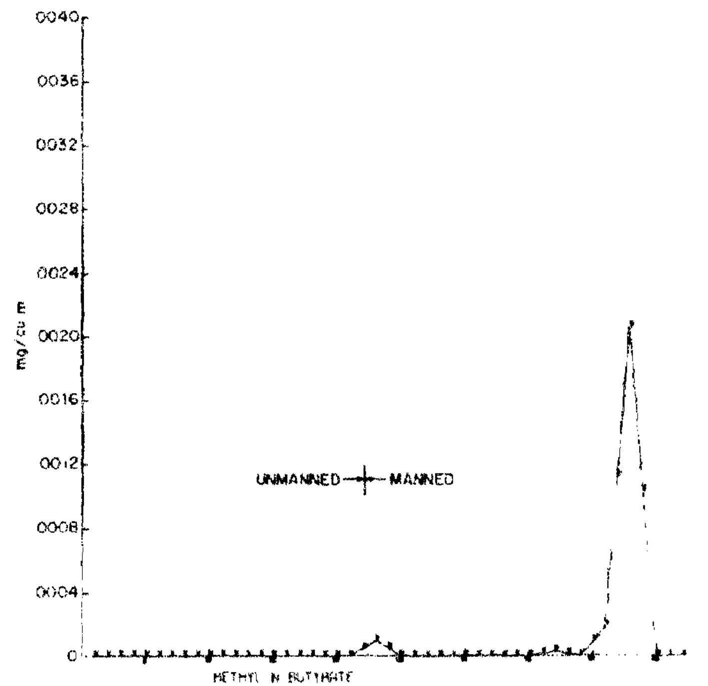

mg/cu m
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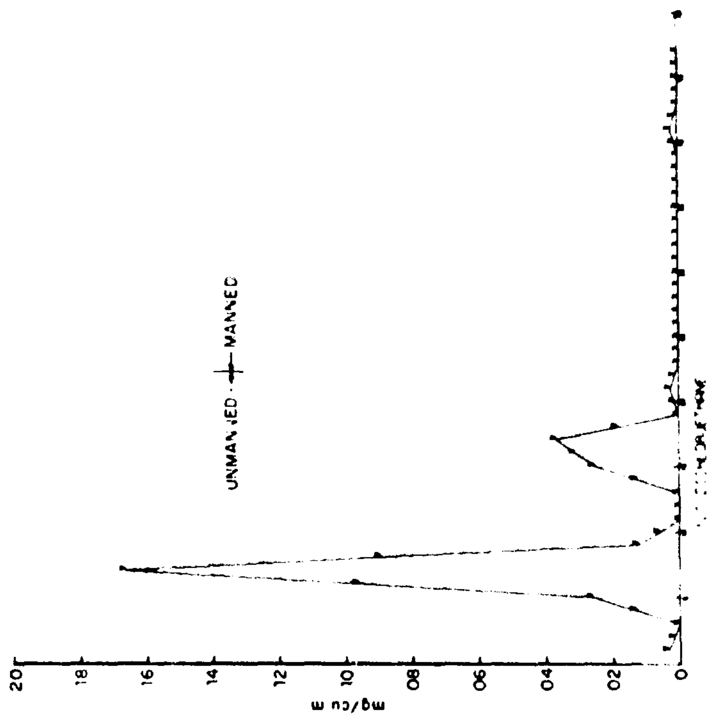
METHYL N BUTYRATE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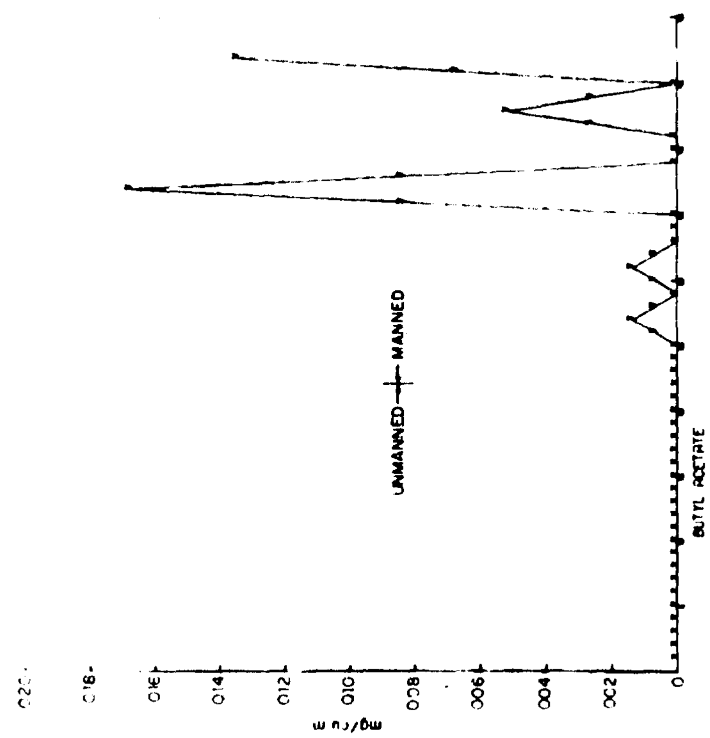
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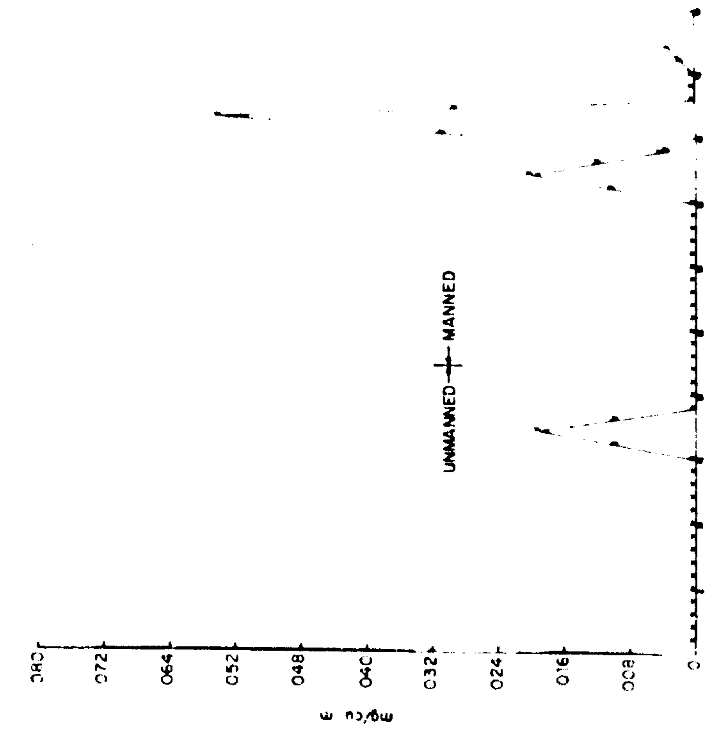
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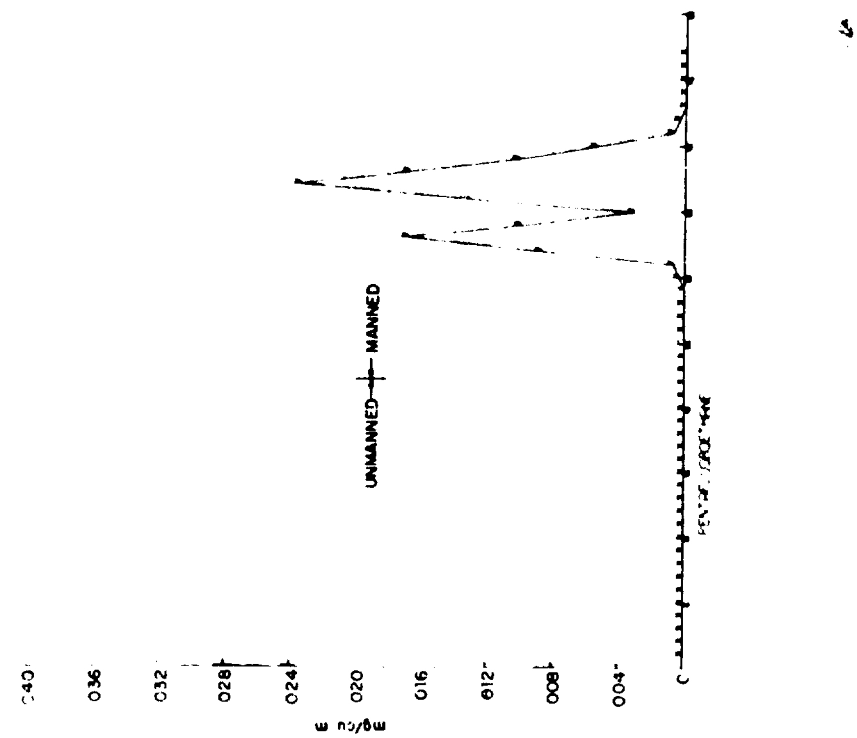
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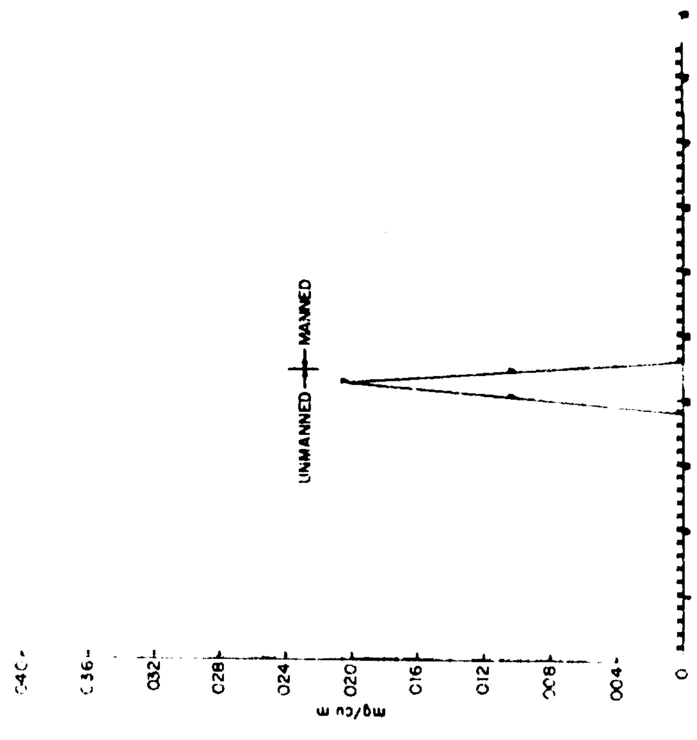
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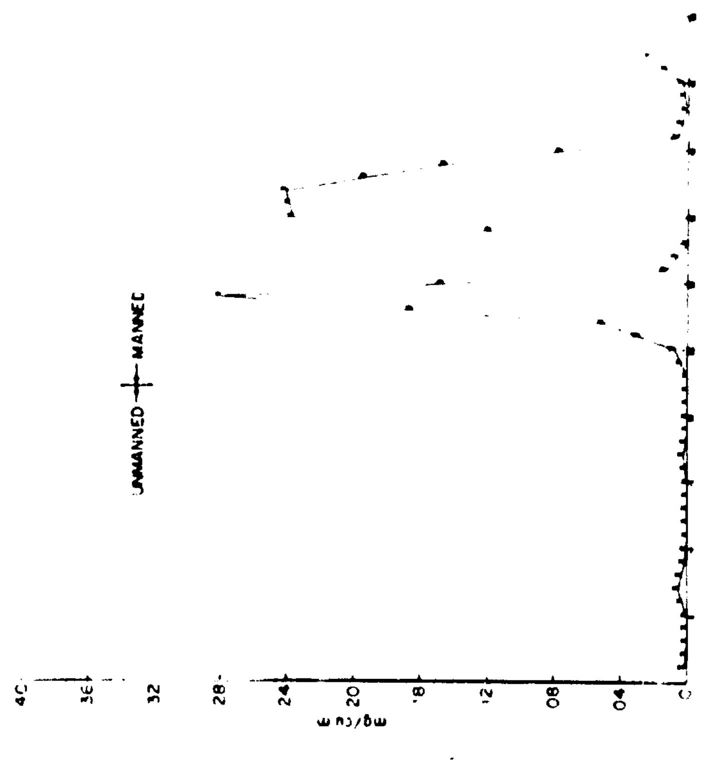
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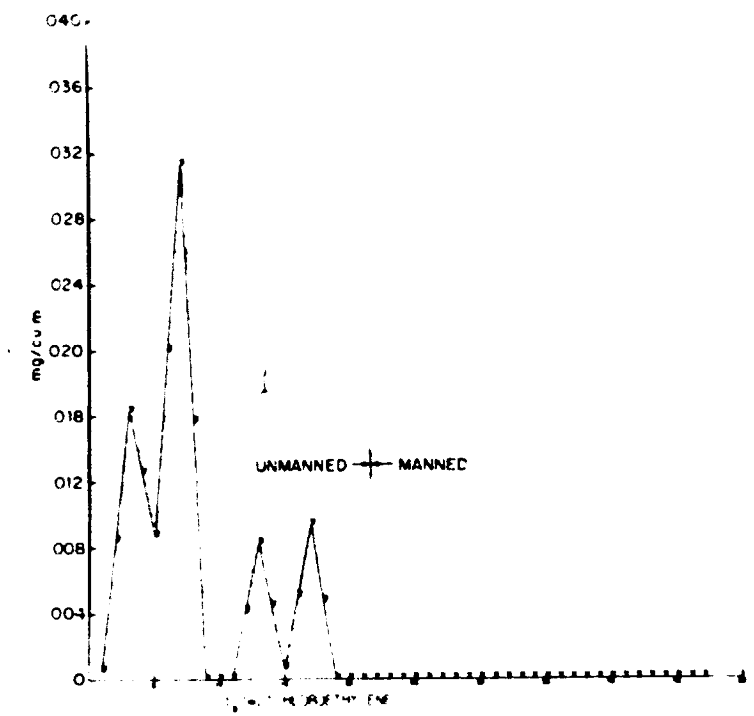

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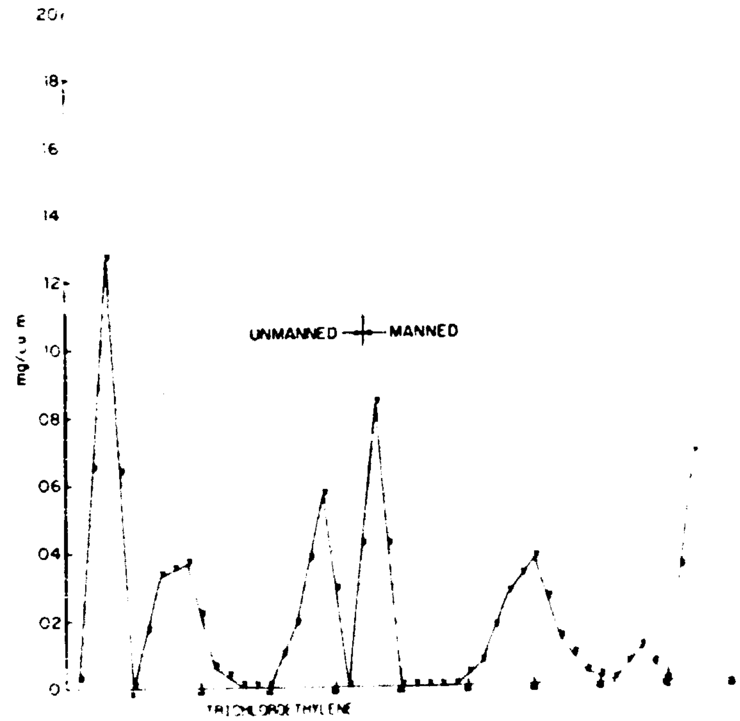

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mg/cu m
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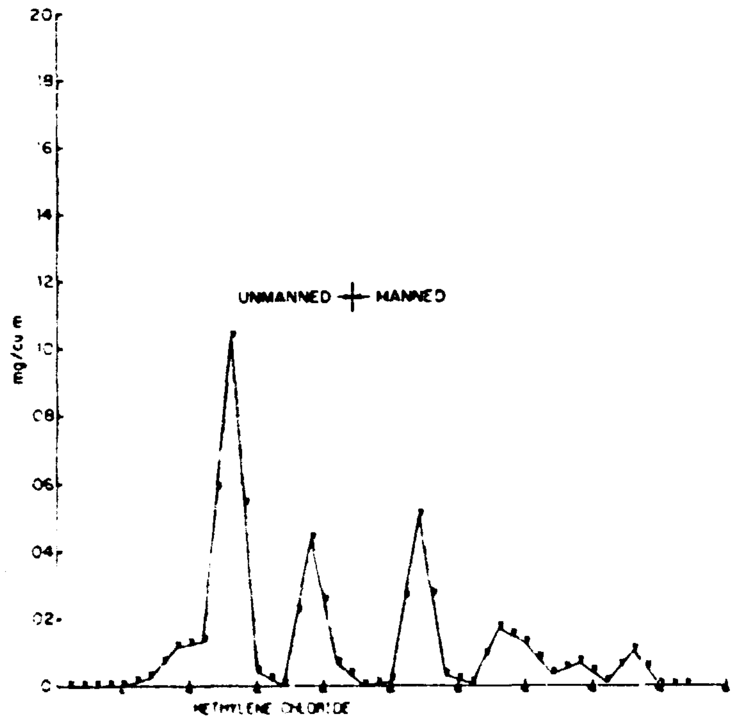

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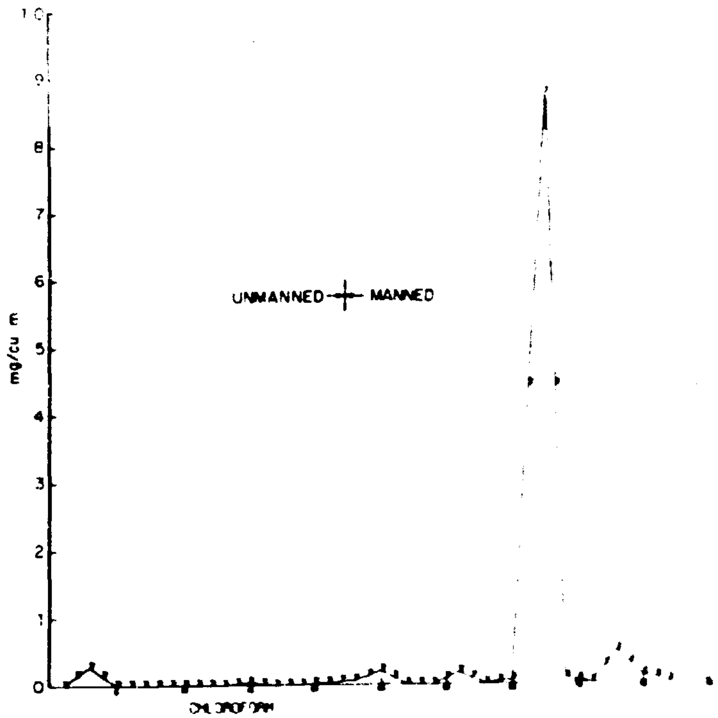
METHYLENE CHLORIDE



mg/cu m
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3
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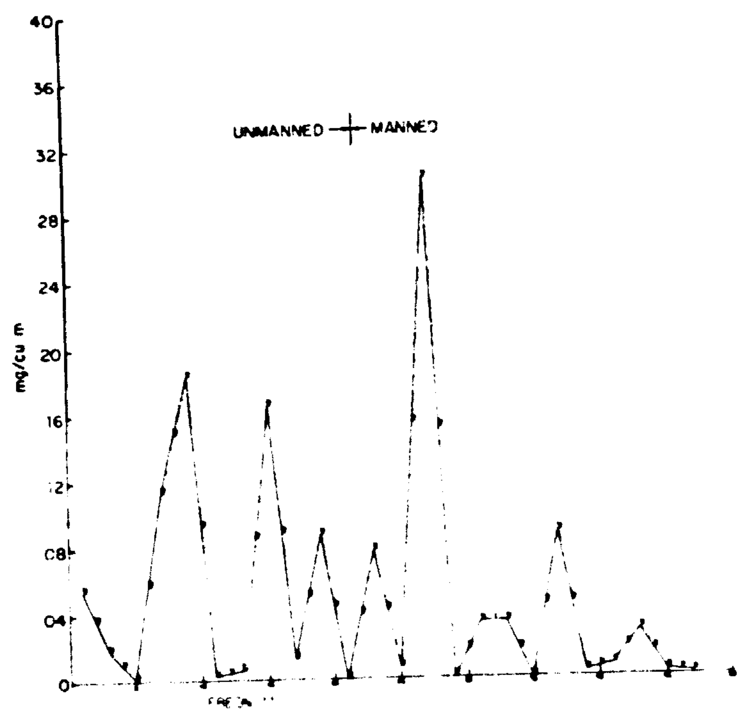
CHLOROFORM



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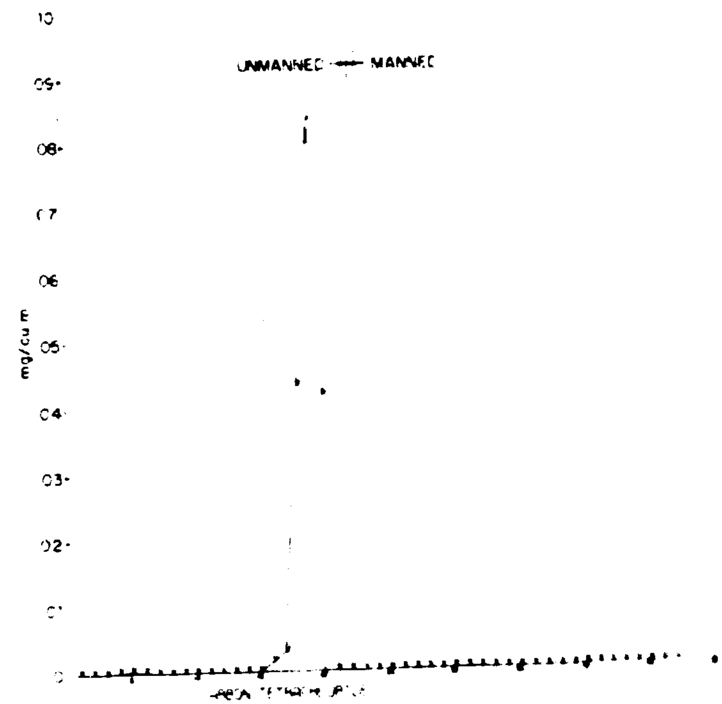
mg/cu m



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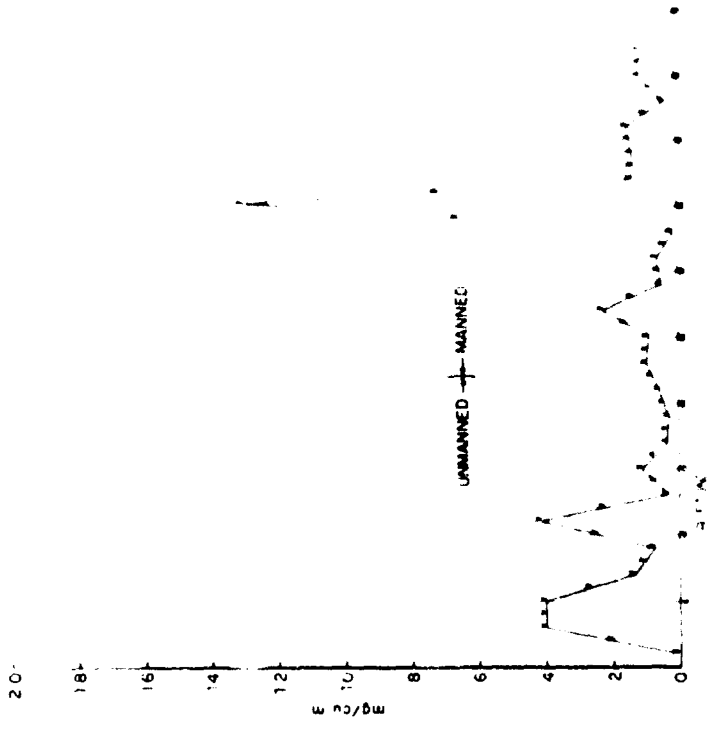
mg/cu m



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MANNED
mg/cu m
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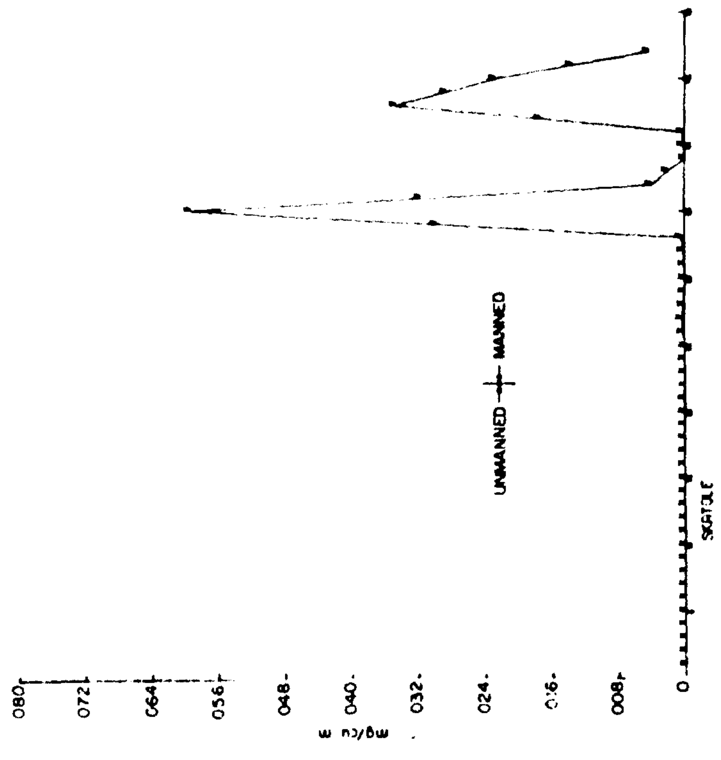

UNMANNED
MANNED
SKATOLE
mg/cu m
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.024
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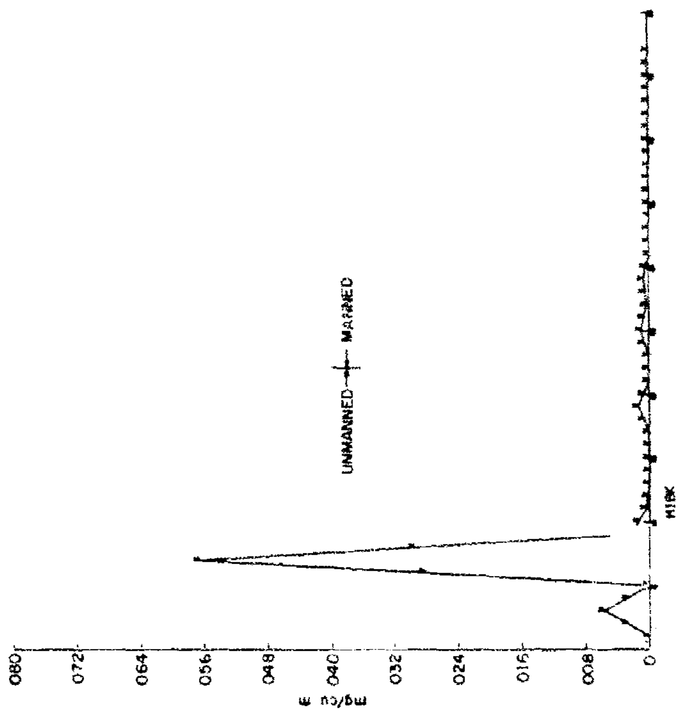
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mg/cu m
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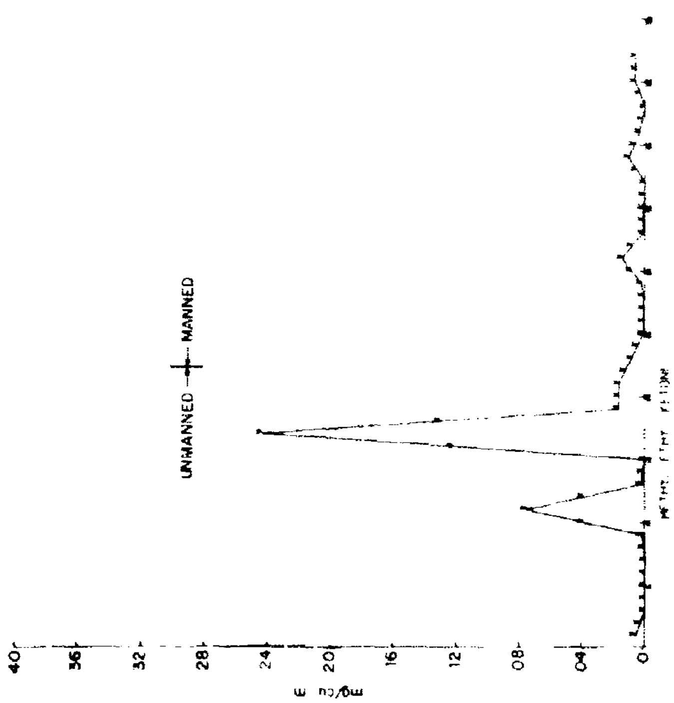
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MANNED
mg/cu m
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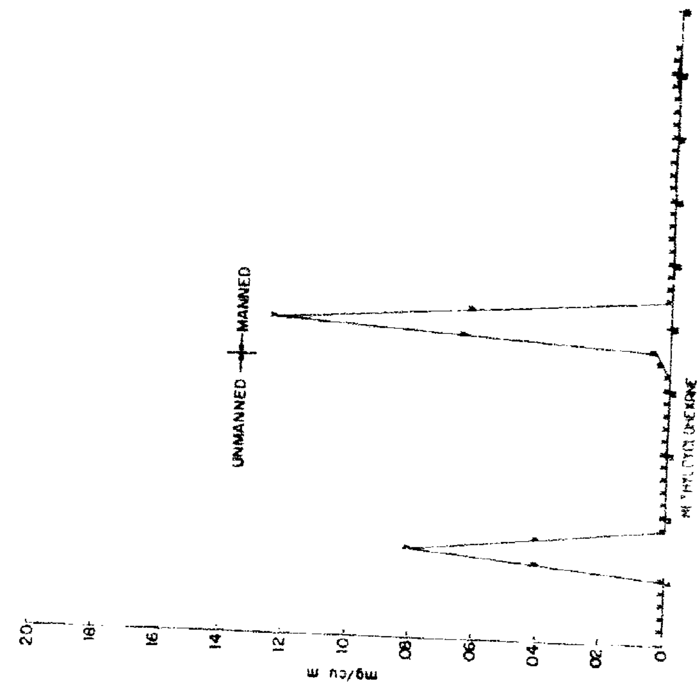

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MANNED
mg/cu m
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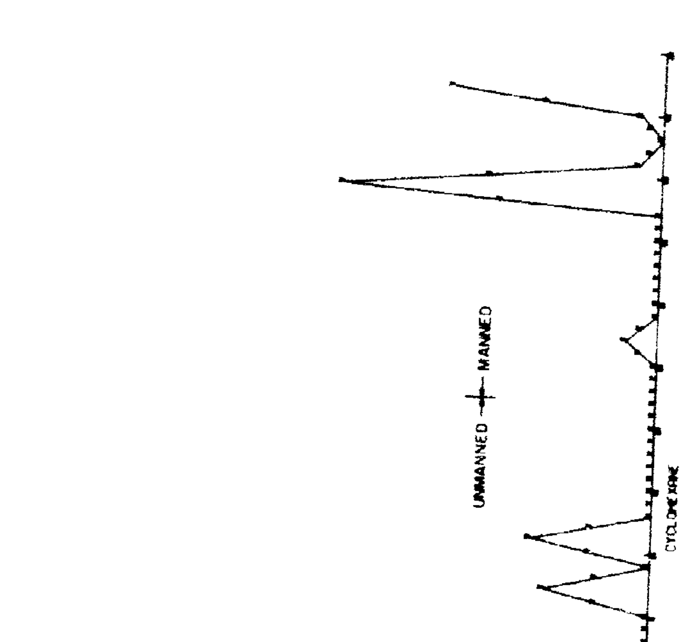

UNMANNED
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mg/cu m
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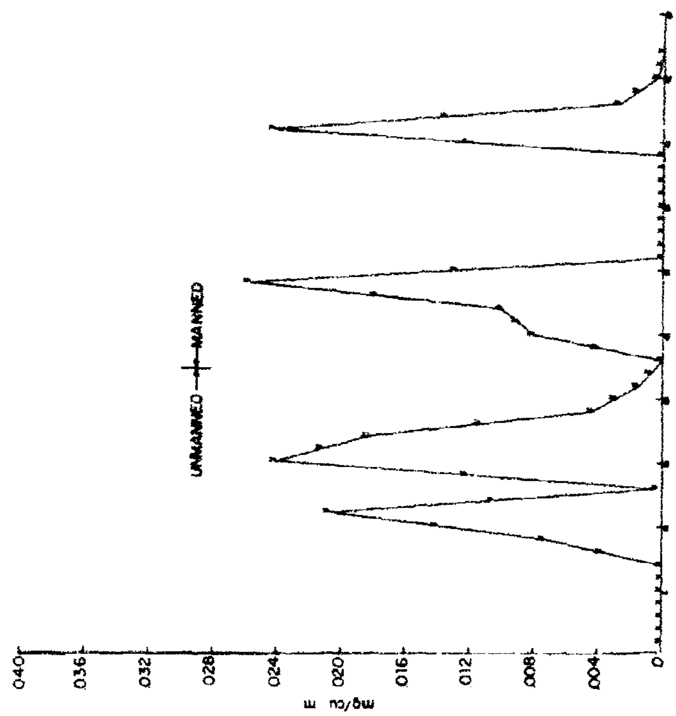
0018
0016
0014
0012
0010
0008
0006
0004
0002
0



UNMANNED MANNED
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mg/cu m
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028
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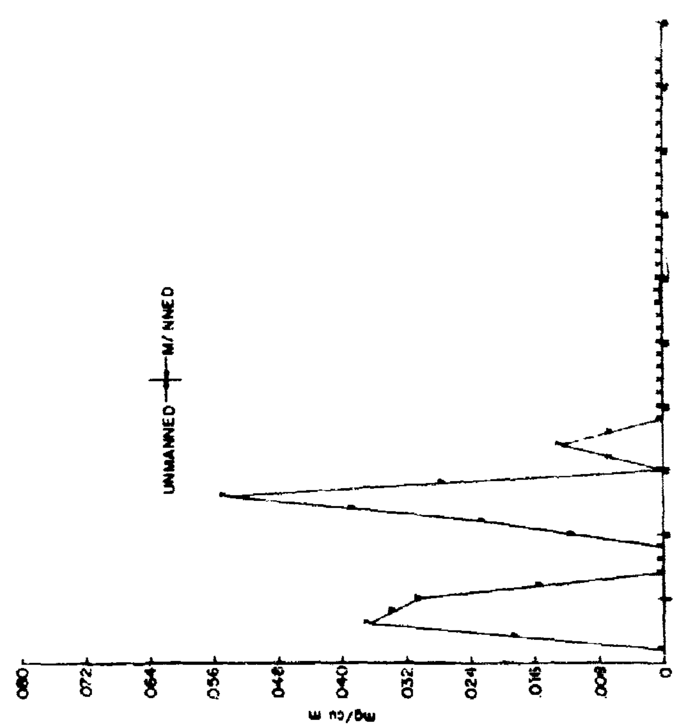

UNMANNED M/ NNED
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mg/cu m
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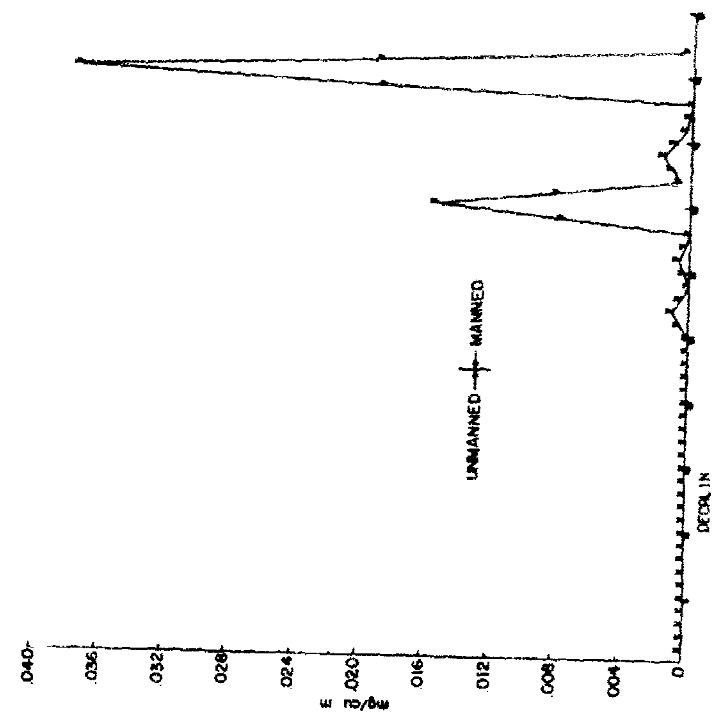
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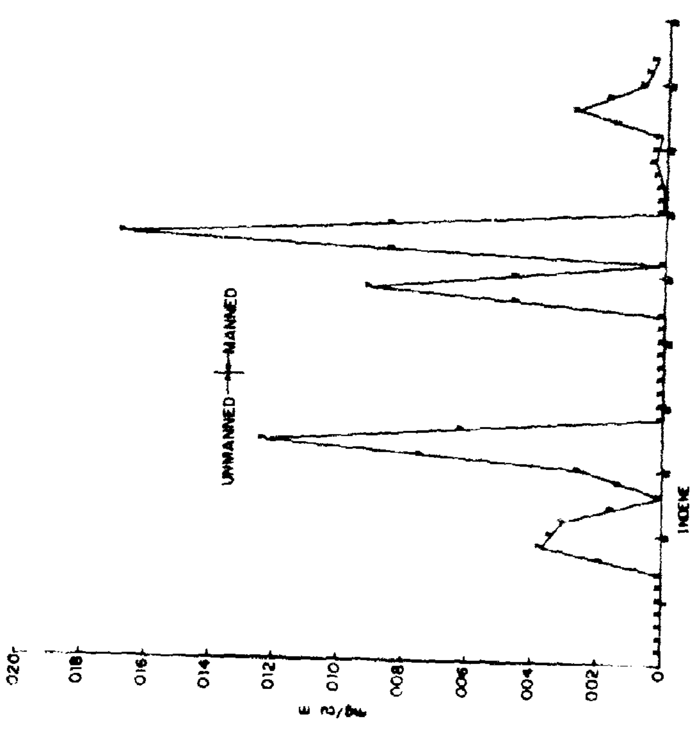
mg/cu m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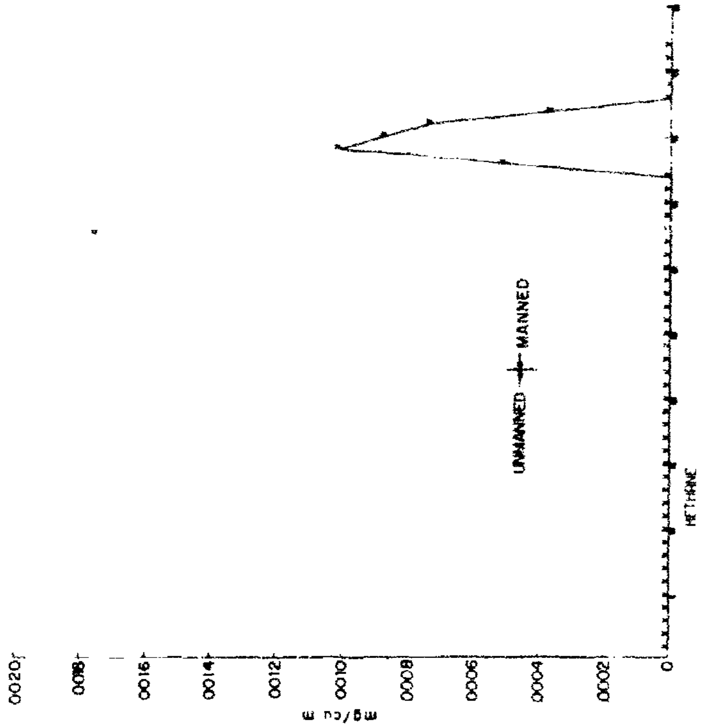
mg/cu m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METHANE
mg/cu m
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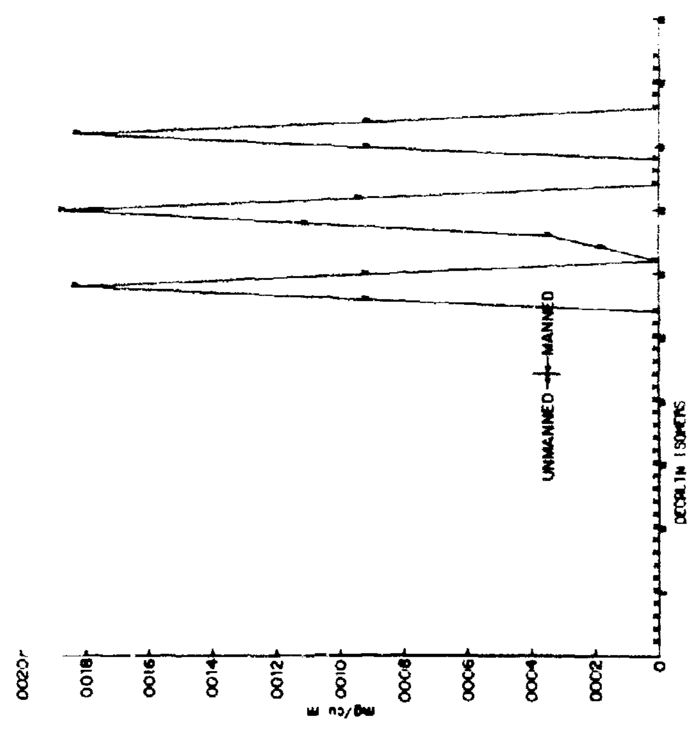
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mg/cu m
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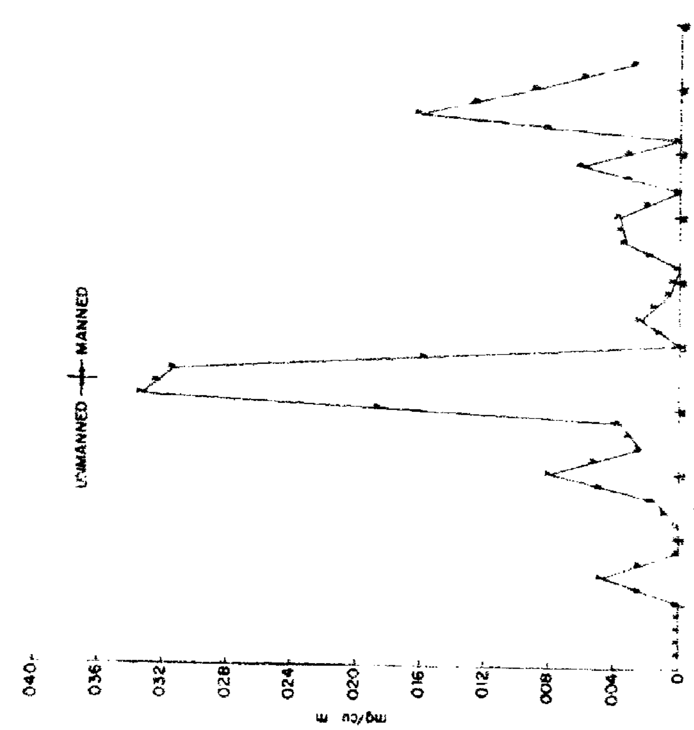

UNMANNED —+— MANNED
mg/cu m
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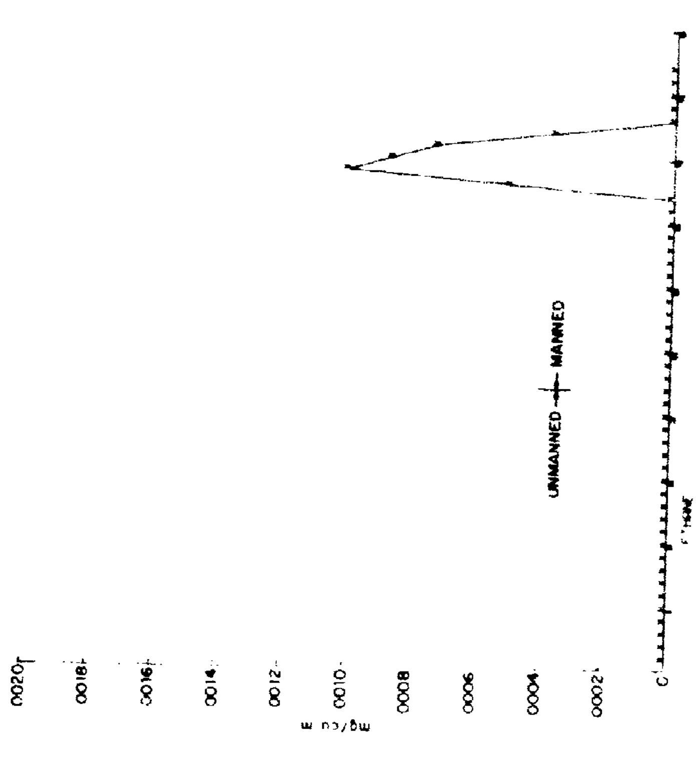

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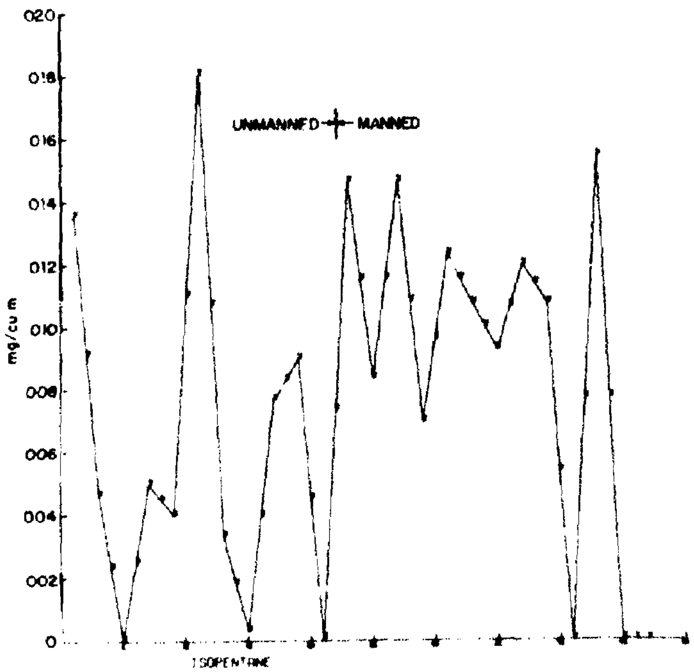
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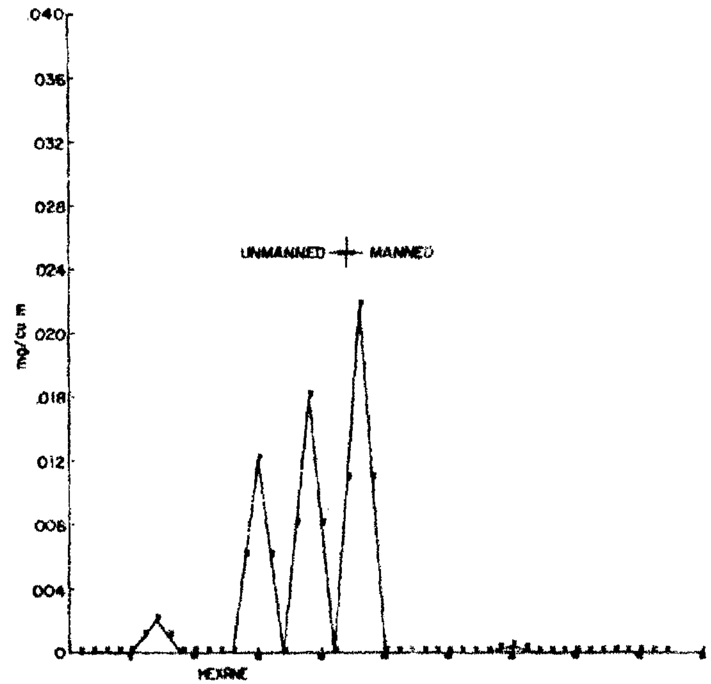
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mg/cu m
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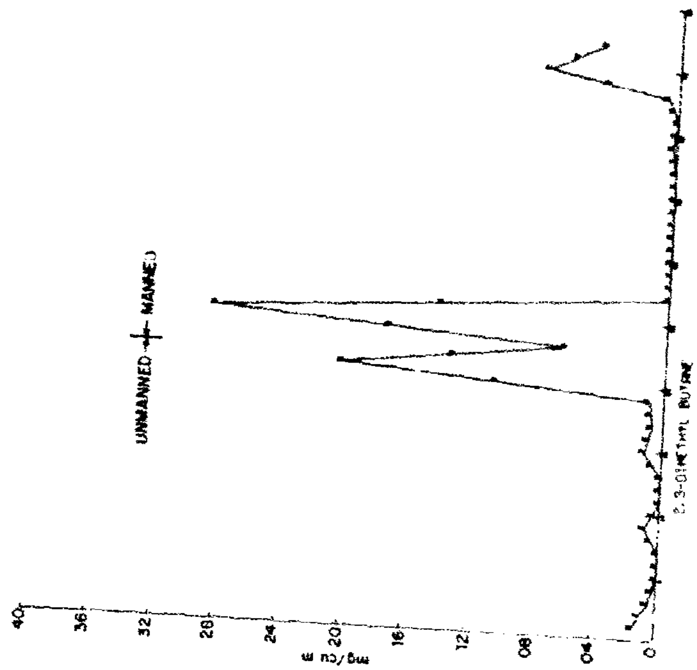
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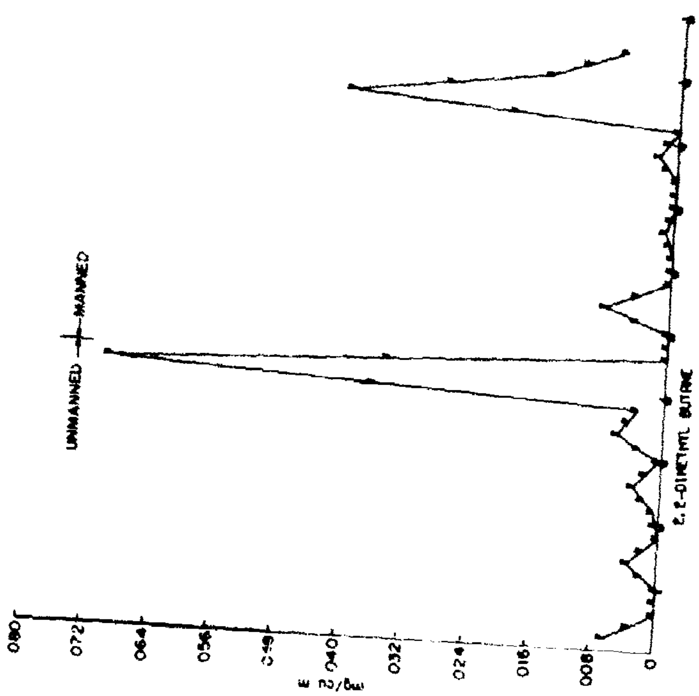
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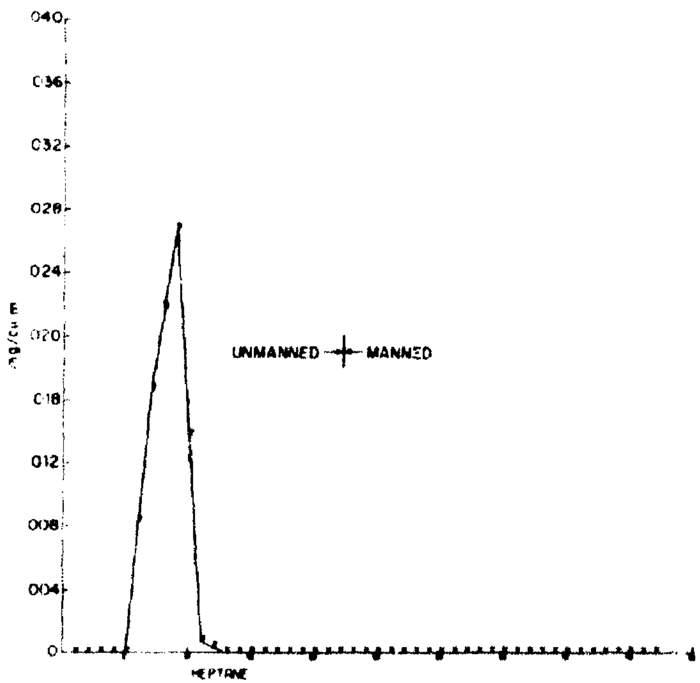
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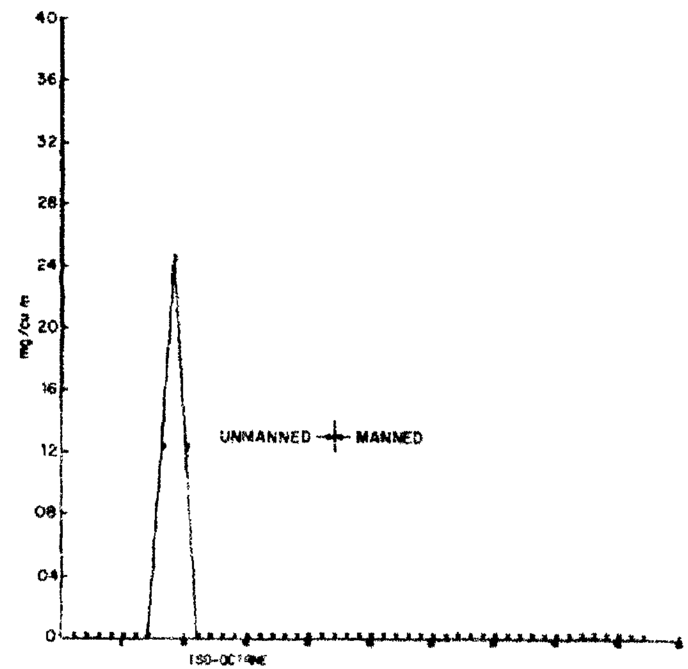
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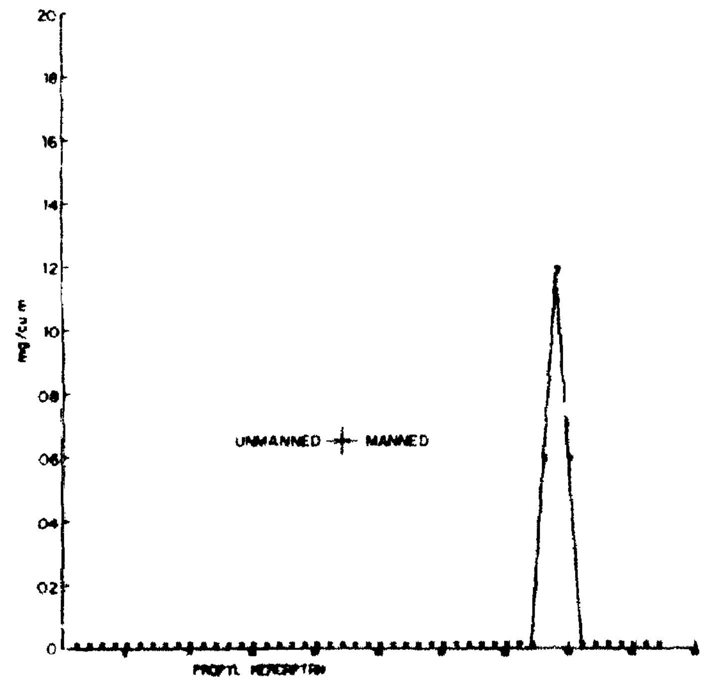
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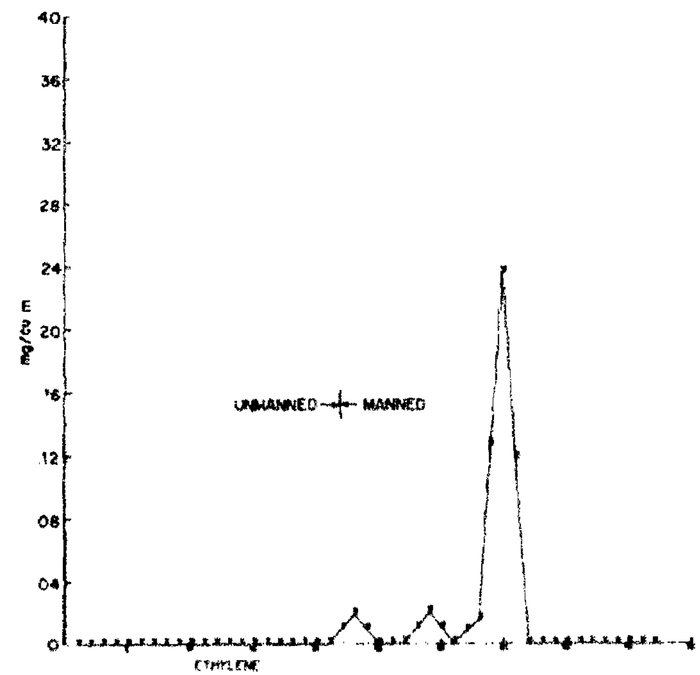
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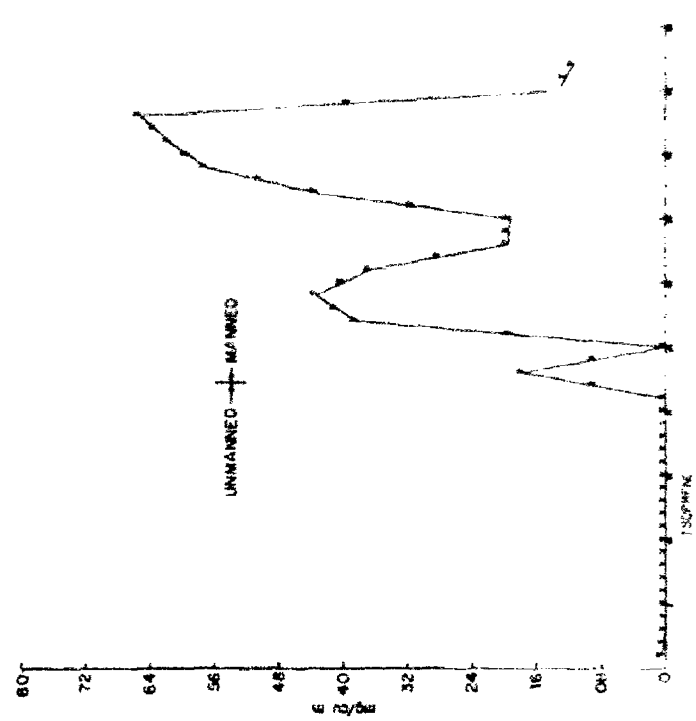
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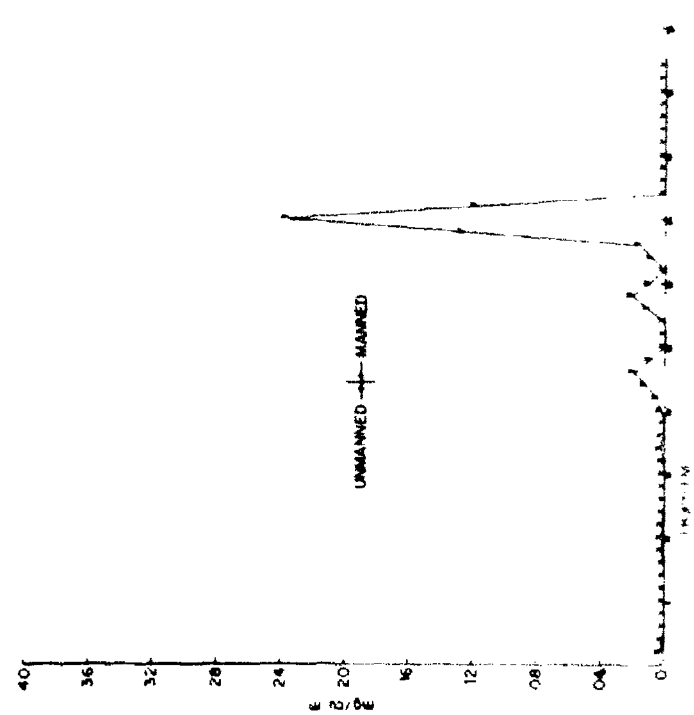
UNMANNED
MANNED
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DOCUMENT CONTROL DATA - R&D

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3. REPORT TITLE

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4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final report 2 - 29 June 1965

5. AUTHOR(S) (Last name, first name, initial)

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Mabson, W. E. Welch, B. E.
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13. ABSTRACT

A 27-day experiment was conducted to determine man's contribution to trace contaminants in a sealed environment. An environmental test cell was maintained at a total pressure of 760 mm. Hg throughout the 27 days, with the first 13 days being unmanned and the last 14 days being manned. Four subjects were utilized during the 14-day manned portion of the test. During the 27 days, 97 compounds were identified and quantified; 21 of these compounds were noted only during the manned portion of the study. Direct contaminant analysis of the sealed environment was not adequate for this type of comprehensive survey. Cryogenic fractionation and concentration, however, provided samples with sufficient concentration of contaminants for analysis by means of gas chromatography, infrared spectroscopy and mass spectroscopy. Carbon monoxide and carbon dioxide were compounds that were produced by man and identified in this experiment and that would require removal during the 14-day period.

DD FORM 1 JAN 64 1473

Unclassified
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Aerospace medicine						
Contaminants produced by man in space cabin simulator						
Space cabin environment						
Gas chromatography						
Infrared spectroscopy						
Mass spectroscopy						
Cryogenic fractionation						

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